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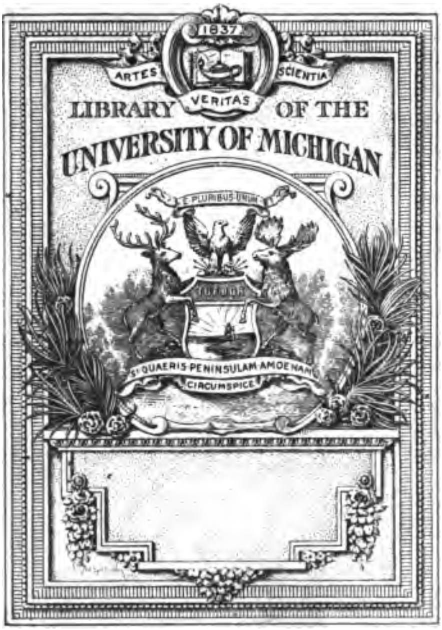
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THE

PRINCIPLES OF PHYSIOLOGY:

THE STRUCTURE OF THE SKELETON
AND OF THE TEETH:

AND THE

VARIETIES OF THE HUMAN RACE.

With an Introductory Treatise

ON THE NATURE, CONNECTION AND USES OF THE GREAT DEPARTMENTS
OF KNOWLEDGE.

THE PRINCIPLES OF PHYSIOLOGY,
BY THE EDITOR.

STRUCTURE OF THE SKELETON AND TEETH,
BY PROFESSOR OWEN, F.R.S.

VARIETIES OF THE HUMAN RACE,
BY R. G. LATHAM, M.D., F.R.S.

Second Edition.

LONDON:
W^M. S. ORR AND Co., AMEN CORNER, PATERNOSTER ROW.
MDCCCLIV.

ORR'S

CIRCLE OF THE SCIENCES.

A Series of Treatises

ON

THE PRINCIPLES OF SCIENCE,

WITH THEIR APPLICATION TO PRACTICAL PURSUITS.

ORGANIC NATURE.

VOLUME I.

Second Edition.

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PREFACE.

In presenting to the Public the First Volume of the "Circle of the Sciences," a few words, explanatory of the general design as originally announced, and of the spirit in which it has been carried out, may be required.

In the Introductory Treatise to this Volume, an attempt has been made to expound, in brief and lucid terms, the general nature, relations, and applications of all the chief departments of Human Knowledge, in order to give the Reader, not specially trained in Science, a general view of the vast field of inquiry which the Creator has laid open to the lawful exercise of the human intellect. Thus the Student has been led, in the first instance, and it is hoped by no rugged or precipitous ascent, to the summit of an eminence whence he may take a survey of the various departments of knowledge, and of the principles which ought to guide him in the pursuit and application of the several Sciences.

In the Treatise on the Physiology of Animal and Vegetable Life, the duties or functions of the organs in the living bodies of plants and animals are defined and classified; and the results of a complete analysis of the constituents of these organs are given, after they have been reduced by the anatomist to their component textures, and by the chemist to their proximate and ultimate elements. The principal modifications of the functions are traced through the different classes of animals, and the leading phenomena of the development of the germ and embryo, in both the divisions of the organic world, are described. The endeavour of the Author has been to compress into the compass assigned to each essay an outline of the chief characteristics of life in the two great departments of Organic Nature, a statement of the relations of Plants and Animals to each other, and an account of their common dependence on the mineral or inorganic world.

In regard to the structure and conformation of that great division of the Animal Kingdom called "the Vertebrate," to which Man himself belongs, and which includes the animals that most resemble Man, it has been deemed sufficient for present purposes to restrict the Essay to the fundamental structures or framework of the body, with the appendages of a like enduring material called the Teeth. The execution of this part of the "CIRCLE" has been confided to that great philosophical anatomist who has so distinguished himself in working out the true principles of Osteology—principles which will doubtless soon be applied to the nomenclature and descriptions of every branch of Anatomical Science. Avoiding the common practice of intrusting the special essays to literary compilers and abridgers, it has been part of the design of the work—hitherto with success—to engage, in the important task of teaching, those master-spirits who have in their day effected the greatest improvements, and made the most decided advances, in their respective departments of science. The result has been, as is especially shown in the "Essay on the Principal Forms of the Skeleton," an original exposition of the principles of Anatomical Science, and of the most important results that have been attained by its latest cultivator:—such exposition being succinct without any important omission, and as clear and comprehensible as is consistent with the inevitable use of technical terms.

New and clearly defined ideas must be expressed by their appropriate signs. The explanation of the sign teaches the nature of the idea. Without learning and understanding the technical terms of a science, that science cannot be comprehended. The terms seem "hard" only while the ideas which they represent are not understood. We listen with pleasure and surprise to the glib facility with which the working classes, admitted in homely attire at half-price to the Zoological Gardens on Mondays, talk of the Elephant, the Rhinoceros, and the Hippopotamus. These derivations from the Greek are no harder to them than the Saxon monosyllabic names of the bear, the seal, or the lion: and yet the four-syllabled and five-syllabled names above cited are longer than the average of the technical terms derived from the same learned and pliable language: — for example, Alisphenoid is not really harder than rhinoceros, nor Neurapophysis than hippopotamus; and when the mind becomes as familiar with the things of which these are the verbal signs, they fall naturally and easily into the circulating medium for the currency of thought. To the intelligent reader of every class, who may be blessed with the healthy desire for the attainment of knowledge, let it then be said—Be not dismayed with the array of "hard words" which seems to bar your path in its acquisition. Where such words are invented or adopted by the masters in science, be assured that your acquisition and retention of their meaning will be the safest "first steps" in the science of your choice.

Where plain and known words of Saxon or old English root could convey the meaning intended, the writers have sedulously striven to use them instead of terms of more exotic origin. But where the signification of a thing, or group of things, would have demanded a round-about explanation, or periphrase, as the alternative for abandoning the single-worded and clearly defined technical term, they have not hesitated to use such term, appending, either in the same page or in the Glossarial Index, its derivation and meaning.

In reference to the terms of Anatomy, a method has been adopted further to facilitate their reception and easy recognition by reference to the part itself so signified in the woodcuts; the same or corresponding part bearing the same numerals in all the cuts: thus the scapula, or blade bone, is indicated by the No. 51 in the fishes' skeleton, Fig. 9, and in all the succeeding skeletons up to those of the Ape and Man, Fig. 46.

The chief phenomena of animal and vegetable life, and the foundation of Anatomical Science, in that department of it which has now reached the highest degree of philosophical symmetry and precision, having been treated of in the Essays on Physiology, on the principal Forms of the Skeleton, and on the Structure of the Teeth in the Vertebrated Classes of Animals, our First Volume—completing the first division of Organic Nature, as introductory to the study of General Zoology—appropriately terminates by a summary of the latest acquired knowledge respecting the "Varieties of the Human Species," from the pen of the chief Ethnologist of the age.

When the amount of exact and original information, condensed in the following pages, is summed up, and the rich series of woodcuts which illustrates that information is studied, the reader will doubtless acquire a conviction that so much valuable matter, and such means of mental improvement, were never before placed within his reach at so cheap a rate.

The principles which have guided the Editors in the production of the First Volume of the "CIRCLE OF THE SCIENCES" will be rigorously adhered to, until that CIRCLE is completed. The development of the plan, as originally conceived, will proceed with uninterrupted punctuality; and the Public may rest assured that this first blossom, now offered in the promising season of spring, may be accepted as a type and pledge of the mature fruit which will follow in autumn.

AMEN CORNER, *May*, 1854.

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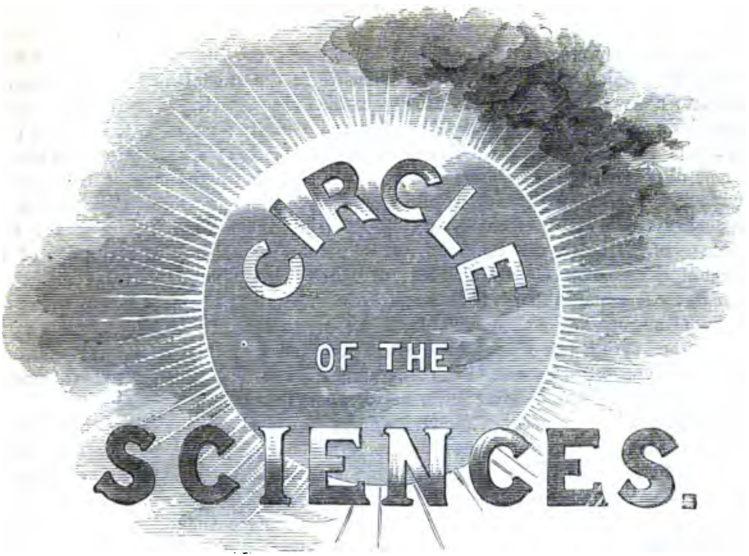


ON THE NATURE, CONNECTIONS, AND USES OF THE GREAT DEPARTMENTS OF HUMAN KNOWLEDGE.

Before man became a philosopher he was a discoverer; and in his capacity for discovery, and for reasoning on its results, he differs widely from all other beings. In the organic world there is no history but the history of man. The doings of one pair, or of one colony of inferior animals, however sagacious, are the doings of generation after generation. Birds build their nests in our gardens and shrubberies as they built their nests in Eden; the bees in our hives construct their honeycomb, as the bees of Samson's time did that which he took from the lion's carcase; and the beavers of Canada rear their dams, and huts, and burrows at this day as they have done ever since their species was created. How different is the account of man's proceedings from the time of his first appearance upon the earth! What variety in his modes of clothing himself—of building habitations—of defending himself from beasts of prey—of transporting himself from place to place—of subjecting to his power the animate and the inanimate Creation!

In the first advances made by primitive man, his capacity for the attainment of knowledge shines forth almost as vividly as in the discoveries made during his most advanced state of civilisation. To draw a distinction between the faculties of man and the faculties of the highest among the animal creation has always been a task of much difficulty; and yet how frivolous appear the attempts to trace a proximity between endowments but outwardly similar, the moment the actual fruits of man's faculties are contrasted with the nothingness of effect produced by any other species on the surface of the earth! It can hardly indeed be said with truth that man's mere senses are more perfect than those of the animals which stand near him in the scale of being; but it is an obvious truth that he has a capacity to originate ideas which mould the observations of sense on a higher and more perfect type.

In man's early progress, the rudiments of almost every branch of knowledge may readily be traced. His intellectual pre-eminence in the animal kingdom may be reduced to a few prominent heads—namely, to his great capacity, in the first place, for appreciating the abstract relations of number and quantity; secondly, to his exact perception of the resemblances and the differences of objects of sense; thirdly, to his inherent disposition to form objects and appearances, which agree even in one quality or mode of presenting themselves, into groups—which are afterwards to be recognised as possessed of a unity of character; fourthly, to his complete feeling of the distinctness of his bodily self from the rest of nature; to his instant perception of its slightest change of position or attitude; and, to his almost unlimited voluntary power over its movements, so that it becomes an exact measure of the numerous relative properties of surrounding bodies; and, lastly, to his capacity for looking inwards upon himself, and taking note of the special effects produced on his internal nature by persons, and things, and circumstances. With these several heads the great departments of human knowledge, as we shall discover, intimately connect themselves.

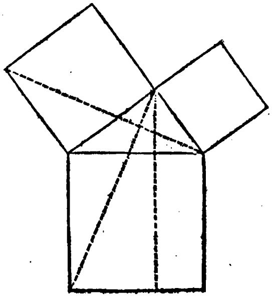
Science.—The systems of knowledge founded on intuitive convictions of the human mind, to which the name of science is currently given, are, in particular, the Abstract or Mathematical Sciences. Those collected from the perceptions of sense, with or without the aid of instruments and of the abstract sciences, and methodised by man's faculty of grouping individual appearances into compound unities, are the Inductive Sciences, under which falls the chief part of physical knowledge—namely, several branches of Natural Philosophy, the whole of the Electrical sciences, Chemistry, and some parts of Physiology. Those founded in the same manner upon the organic kingdoms of nature, with the aid of certain fundamental intuitive convictions of the human mind, constitute the Physiological sciences. Those directly deduced from man's contemplation of the subjects of his consciousness, and the report of others as to the results of their reflections on what consciousness has taught them, make up the Psychological sciences, Metaphysics, Ethics, &c. Those drawn from the contemplation of man in his social state, as bearing on the welfare of the community, are represented chiefly by Statistics and Political Economy. Those which rest on moral evidence, in its three degrees of possibility, probability, and moral certainty, rather than on the evidence of sense, are Government, Law, Medicine, Taste, Criticism, &c. Those which are formed by comparing the substances composing the exterior of our planet, and the individuals of the animal and vegetable kingdoms, and by marking their resemblances and differences, constitute the Natural History of the three Kingdoms of Nature. And lastly, the systems of knowledge derived from the observation of the minute structure of minerals, plants, and animals, and the grouping of certain frequently recurring resemblances into separate unities, each denoted by a single expression, constitute what have been termed the Descriptive Sciences, such as Zootomy, or Anatomy commonly so called, Phytotomy or Vegetable Anatomy, and Crystallography.

Such, then, is an enumeration of the great branches of human knowledge, of which it is our intention in the present undertaking to treat. But, at present, let us examine more narrowly the resemblances and differences of the evidence on which these several branches of knowledge depend, and endeavour to ascertain their connections and the precise uses to which each is subservient.

We will premise, however, that although the name of science is currently applied to the more profound parts of man's studies, the term has no definite signification. In particular, it is employed indiscriminately to denote those systems of knowledge which are deduced from the inherent or intuitive convictions of the human mind, as well as those systems of knowledge which are built upon the perceptions of sense, variously grouped into a whole, because of the agreement of the members of each group in one mode of presenting themselves. But vague as is the term science, it is too firmly rooted to be rejected.

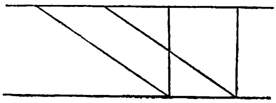
Geometry.—When any part of Mathematics, for example, Geometry is compared with some one of the Inductive Sciences, such as Chemistry, it is discovered how loosely the term science must be used to apply equally to both. For this purpose, we select for contrast the properties of the alkalies, on the one hand, and on the other the remarkable property of the right-angled triangle, that the square of its hypotenuse is equivalent to the sum of the squares of the two sides. The alkalies—that is, the pure caustic alkalies —are freely soluble in water and in alcohol; each saturates its own proportion of every known acid; and were a new acid discovered, it would only be necessary to ascertain how much of it is required to saturate a given quantity of one of the alkalies, to pronounce how much of each of the others that same quantity would saturate; the alkalies, besides, form soaps with oils; they change vegetable blue colours to green, and yellows to brown. By means of these properties, the chemist is able to detect the presence of any pure alkali in his analysis; and such is one of the great objects which the science of Chemistry has in view. But the point which we wish chiefly to be borne in mind is, that from the whole history of Chemistry no reason can be elicited why an alkali should be soluble in water rather than insoluble, or soluble in alcohol rather than insoluble; why it should combine with oils or acids rather than resist combination with them; why it should change vegetable blues to green, and yellows to brown, rather than to any other colour. In the conception of properties, as belonging to the alkalies, opposed to all those just enumerated, there is nothing contradictory. In short there is no reason why any peculiar property of an alkali, so far as the human faculties can comprehend, should not, in the arrangement of nature, have been the opposite of what it actually is. And the same may be said of all those laws and properties in nature which are discovered solely by observation.

On the contrary, when the several steps are considered by which an equality is proved between the square of the hypotenuse in a right-angled triangle, and the sum of the squares on its two sides, there is not discoverable, in the whole course of the demonstration, any single truth, the opposite of which does not involve a contradiction; so that, independently of any observation, the human mind is, by its very nature and constitution, compelled to extend to them an absolute and unconditional belief.



The square described on the hypotenuse being cut by a straight line in such manner as divides it into two distinct parallelograms, it is at once shown by the undeniable proposition, that if two equals have each an equal quantity added to them, the sums are equal; and then by the undeniable proposition that the doubles of equals are equal to one another—that each of the two divisions of the square on the hypotenuse is equal to one of the squares on the two sides of the triangle.

The proof of the theorem just referred to, may readily be understood even by one unversed in the elements of geometry. With the meaning of parallel lines every one is familiar. Here are three pairs of parallel lines; one pair running from side to side, and two pairs between them, forming two parallelograms or rectilinear figures, the opposite sides of which are parallel. These two parallelograms stand upon the same base, and lie between the same parallels; and when this is the case parallelograms are equal—that is, the area of the more upright of these two figures is equal to the area of the more slanting figure. And the truth of this will appear at once, by considering how the whole figure, composed of the two parallelograms taken together, is made up. If from this whole figure the more upright of the two parallelograms be taken, a triangle remains; and if from the whole figure the more oblique parallelogram be taken, another triangle remains. But these two triangles are equal, their corresponding sides and angles being equal; hence the parallelogram which remains, after one of these triangles is taken away, must be equal to the parallelogram which remains after the other triangle is taken away. Such, then, is the proof of the proposition, that parallelograms between the same parallels, and standing on the same or an equal base, are of the same area; and as every parallelogram is divisible into two equal triangles by its diagonal, it follows that triangles standing on the same base, and between the same parallels, are of the same area.



Let us now return to the figure on the preceding page, representing the squares on the three sides of a right-angled triangle. In this figure there is a triangle standing on the same base, and between the same parallels as the square on the left-hand side of the triangle, and there is a triangle standing on the same base, and between the same parallels as the larger of the two parallelograms into which the square of the hypotenuse is divided; but these two triangles are equal, owing to the equality of two sides, and the contained angle; hence the square, which is equal to twice the area of one of these equal triangles, is equal to the parallelogram, which is equal to twice the area of the other triangle. And by the same mode of reasoning, the square on the right-hand side of the triangle is proved to be equal to the lesser of the two parallelograms into which the square of the hypotenuse has been divided.

But in the whole range of Geometry the proposition holds good, that every stage of the proof is a truth, the opposite of which involves a contradiction; and therefore, that it is itself a necessary article of belief. In short, it is incontrovertible that mathematical truths are necessary truths. Geometricians use various ways of convincing us of this: where two figures are necessarily equal, as a consequence of certain parts in one being known to be equal to corresponding parts in the other, the method of superposition is frequently employed; that is, we are required to fancy one figure placed upon the other, and then, mentally, to bring about their perfect adaptation: the parts, previously known to be the same in both, being properly adjusted, the other parts, by this method, are shown to be necessarily coincident. There is, however, nothing of a mechanical or experimental character in this process: the figures are not bodily transported from one place to another; the whole is a purely mental operation; and it is the mind, not the eye, that sees the complete adaptation of the two.

Some superficial thinkers cavil at the peculiar character assigned to mathematical science, by reference to the very proposition above adduced; saying that the fact as to the equality of the squares, was discovered by observation, and the demonstration afterwards invented; as is proved, they further say, by the tradition, that Pythagoras sacrificed a hecatomb in gratitude to the gods for having inspired him with its discovery. Thence, it may be supposed, they would infer that all mathematical knowledge is founded on observation, and not on intuitive convictions of the human mind.

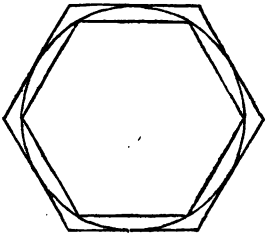
It is evident, however, that many truths, susceptible of a mathematical demonstration, like that respecting the squares on the sides of a right-angled triangle, are discoverable by observation; and doubtless, in the early progress of geometry, this method was much employed to discover the course to be adopted for the extension of this branch of knowledge. But had geometry, or any other part of mathematics, been confined to this method of investigation, would it ever have attained the rank of being the handmaid of inductive science—the very means by which observation has been made capable of deciphering the system of the universe?

The distinction between mathematical truth and inductive science, so clearly pointed out by the contrast between the properties of the alkalies, and the remarkable properties of the right-angled triangle above referred to, is irrefutable.

Magnitude.—We have not hitherto referred to the great object which mathematical science has in view, namely, to supply a measure by which all magnitudes may be rendered commensurable. A few words will give the steps by which this is accomplished in a sufficiently clear light.

By the propositions readily reducible to the truth, before referred to, that two triangles are equal, if their corresponding angles and corresponding sides be equal, any two rectilineal figures, however dissimilar, may be proved to be equal if they really be equal, or unequal if they be unequal. And this may be described as the first great step in Mathematical Science; because, by means of the equivalence of triangles, all rectilineal figures are rendered commensurable.

The next step in Mathematics is to find the measure of figures bounded by curved lines. For example, to find the area of a circle in rectilineal measure.

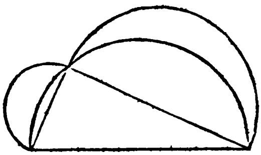


The attempts to find the area of a circle in rectilineal measure gave rise to the proof by the method of "exhaustions," as it is termed.

The area of a circle is a quantity intermediate between the area of a polygon circumscribing the circle, and that of a similar polygon inscribed within the circle. If the number of sides in each of these polygons be successively increased, the area of the interior polygon is continually augmented, while the area of the exterior polygon is continually diminished,—plainly, however, on this condition, that though the area of each continually approaches nearer and nearer to the area of the circle, that of the exterior polygon can never fall short of the area of the circle, nor that of the interior polygon exceed the area of the circle. Thus, as the sides of these polygons may be increased without any limit, the difference between the area of the exterior polygon and the area of the interior polygon is continually becoming less and less, or continually approaching, without reaching, to nothing; and though the rectilineal polygon cannot be made an exact measure of the curvilineal circle, yet it can be made to approach to its measure with any required degree of nearness. It may be remarked here, also, that this operation enables the unlearned reader to understand what is meant when it is said that unity divided infinitely $= 0$.

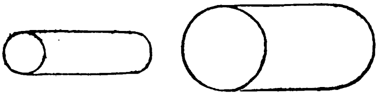
It was another step in Mathematics when the area of curvilineal figures came to be expressed exactly by the areas of rectilineal figures. What are called the "lunes" of Hippocrates, known to the ancients, afforded one of the earliest examples of this coincidence. To exhibit this property, a right-angled triangle is inscribed in a semicircle, and a semicircle described on its base and its perpendicular. The portions of the two last semicircles which lie without the original semicircle, are found to be equal to the area of the triangle.

The following is the kind of proof on which this proposition rests. It is found that if semicircles are described on the three sides of a right-angled triangle, the area of that described on the hypotenuse is equal to the joint areas of the semicircle on the base and that on the perpendicular. But the greater semicircle in the annexed figure consists of the right-angled triangle and the two arches of that semicircle cut off by the sides of the triangle, and the joint areas of the two lesser semicircles consist of the two lunar spaces cut off by the greater semicircle and the two arches of that great semicircle just mentioned; hence, if from each of these two equal quantities, the common quantity in both, namely, the arches of the great semicircle cut off by the sides of the triangle, be taken away, there remains on the one hand the triangle, and on the other the lunar spaces of the lesser semicircles, taken together, equal to each other.

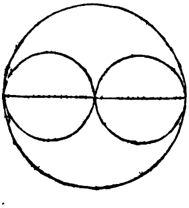


The propositions, on which the proof of this correspondence in equality depend, are easily understood.

The circumference of a circle is proportional to its diameter—a proposition which may easily be shown to be a necessary consequence of the geometrical definition of proportion. It is not, however, so obvious that the area of one circle is to the area of another circle, as the square of the diameter of the first circle to the square of the diameter of the second circle. It is, however, a very important proposition, for if a person supposed that the areas of circles are simply proportionate to their diameters, he might commit many serious errors. For example, if he wished a tube, as a gas-tube, twice the capacity of another tube, and desired it to be made of equal length, but twice the diameter, it would turn out to have four times the capacity; for the square of a line eight inches long consists of sixty-four square inches, while that of a line four inches long consists of only sixteen square inches.



That the areas of circles are not to one another as their diameters, is a truth of which the learner may easily satisfy himself without any knowledge of Geometry; thus: let a circle be described with any diameter, and within it let two circles be described, with the diameter of each only half that of the outer circle; then if a circle, with double the diameter of another, were no more than double that of the other in area or surface, it is plain that the two inner circles would just fill up the outer, which is at once seen to be impossible. It is, however, worthy of remark, that the circumference of the outer circle would be exactly equal to the two circumferences of the inner circles, which is only one among the many interesting and unexpected truths that Geometry presents.



But the great progress made in this part of Mathematics has arisen from the investigation of the areas produced by the higher order of curves, as of the conic sections, exemplified in the ancient discovery that a parabola is equal to two-thirds of its circumscribing parallelogram.

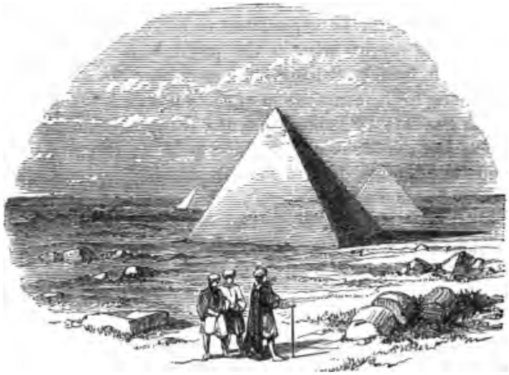
But it would be superfluous to carry these illustrations further, since it already sufficiently appears what is the proper object of Mathematics, and that the evidence employed in this Science uniformly consists of propositions, the reverse of which, according to the constitution of the human mind, involves a contradiction.

Number.—Our observations have been confined hitherto to what relates to magnitude; but the doctrine of number is in no respect different. That 2 and 2 make 4, and that 2 taken from 4 leave 2, are unquestionably intuitive truths—they must be believed; they are necessary truths, because the opposite propositions involve a contradiction. But the truth that 10 times 10 make 100, rests on the same kind of evidence. One repeated a hundred times makes 100. Observation is not required to prove 10 times 10 to be 100; it is merely required to discover if what is called 100 be 100. If, in the primitive state of our race, one man, on giving another figs or dates, held up the fingers of both hands ten times, he who received them would count them, not to ascertain if 10 times 10 were 100, but to discover if he who gave the fruit had spoken truly as to the number.

Mathematical Evidence.—All Arithmetic, then, rests on the same evidence—all its truths are necessary; and the same may be said of Algebra, Logarithms, and the Differential Calculus. Algebra may be described as Arithmetic carried on by symbols; so that the kind of operation is constantly indicated, but not actually performed till the relation between the given quantities and the quantity sought, be reduced to its simplest possible form. Logarithms depend on what seems a singular property of numbers; yet that property is as certainly deducible from necessary truths as any truth in Mathematics. If two series of numbers stand respectively in Geometrical and Arithmetical ratio, it is found that the product of any two numbers in the Geometrical series may be found by adding the corresponding numbers in the Arithmetical series, and then taking the number in the Geometrical series which stands opposite: and this is the product sought.

Logarithms.—The most difficult and complicated arithmetical operations may be performed with ease and expedition by means of Logarithmic tables; and thus multiplication is reduced to addition, division to subtraction, evolution to multiplication, and the troublesome process of involution, or the extraction of roots, to simple division. Astronomy owes much of its pre-eminence, as an exact science, to the discovery of Logarithms, as, without their aid, it would have been almost impossible to have made the calculations necessary to confirm its laws. The astronomer reduces his algebraical formulæ to a form adapted for logarithmic computation; and his assistants, by the simplest rules of arithmetic, are thus enabled to compile the Nautical Almanac, without which the commerce of our great nation would be nearly destroyed—the Nautical Almanac and a table of logarithms being as essential to the mariner as his chart and compass.

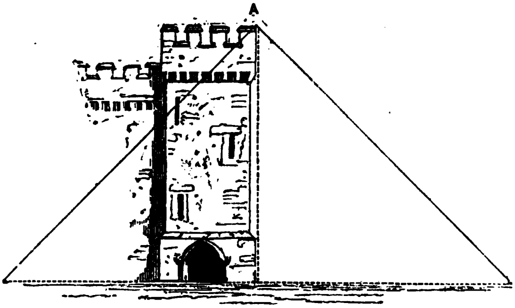
Proportion.—To exhibit a tithe of the uses to which the sciences of quantity and number can be applied, would fill a volume. Still the only practical use of these important sciences, is the measurement of quantities before unknown. The great instrument in all the departments of abstract science is proportion; thoroughly to understand which is to possess an instrument of knowledge applicable to almost every situation in life. When Thales of Miletus travelled into Egypt, 600 years before Christ, and saw the Great Pyramid, he was curious to determine its height, which hitherto it had been



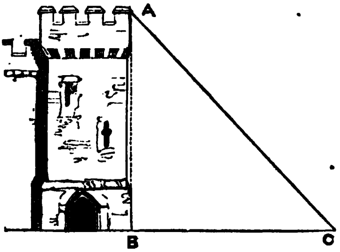
deemed impossible to ascertain. Observing the shadow of the pyramid as the sun shone upon it, stretching far in the opposite direction, he struck his staff upright in the sand; and finding the shadow which it cast to be exactly its own length, he rightly concluded that the shadow, measured from the middle of the base of the pyramid, must equal in length the height of the pyramid. He paced the shadow, and found its length to be 270 paces, or about 500 English feet. Pliny, who relates this anecdote (lib. xxxvi. 17), expressly says that Thales measured the shorter shadow at the time when it was of the same length as the staff.

But although equality in length of the shadow and the body may be allowed to be necessary for the discovery of this mode of mensuration, it would quickly appear without any necessity for experiment, that whatever relation the shadow bore to the staff, the same relation of magnitude would the shadow bear to the height of the pyramid. The three things requisite are, the measure of the shadow of the staff, the measure of the shadow of the pyramid, and the measure of the staff itself. But, to solve this more complex problem, the knowledge of proportion is necessary: namely, that when of four numbers the first two bear the same analogy to each other as the last two to each other, the first of the four, multiplied by the last of the four, is equal to the second multiplied by the third; or, as it is usually expressed, the product of the extremes is equal to the product of the means:—or 4 : 16 : : 20 : 80—that is, 4 is to 16, as 20 to 80; but the product of the extremes, 4 and 80, is 320; and the product of the means, or middle numbers, 16 and 20, is also 320. But when three numbers are known, and a fourth is sought in the same relation to the third which the second holds to the first, it is plain that the product of the means can be obtained; and that that product being also the product of the extremes when both these come to be known, and being divided by the first extreme, the second extreme will be obtained: that is, if in the above formula 16 and 20 be multiplied together, and the product divided by 4, the fourth number, the second of the two extremes, or 80, will be obtained.

And this rule of proportion prevails throughout the whole range of the sciences of magnitude and number. In every kind of measurement proportion plays its part, with the exception of that which is of the rudest kind. In the measurement of the height of the Great Pyramid by Thales, the idea of proportion is involved, although hardly brought out into relief. We will cite another example of the measurement of a height without distinct reference to proportion. The height of a tower or pillar—no matter how high—which stands on a level plain, and the foot of which is accessible, can be measured as soon as men have discovered that in a right-angled triangle, the sides of which are equal, each of the other two angles is equal to half a right angle, and the perpendicular equal to half the hypotenuse. If the perpendicular line in a right-angled triangle represent a tower, it is evident that its height is equal to half the hypotenuse, or side opposite to the right angle at A. Thus, if a person setting out from the foot of the tower pace the distance to the point at which the top of the tower is seen at an elevation of 45°, or half a right angle, the number of paces he has taken indicates the height of the tower.

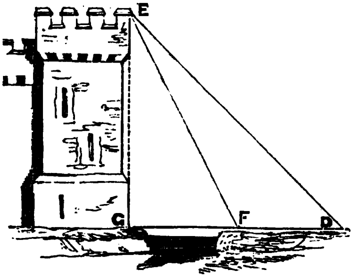


Trigonometry.—The usual mode of determining heights is by the rules of Trigonometry, without any necessity for the angle of elevation being of a particular number of degrees.



When a tower is accessible, the angle BCA is measured, and the base of the triangle CB; the angle at B is known, being a right angle, and the angle at A is found by subtracting the angle at C from 90° or a right angle; because since the three angles of every triangle are together equal to two right angles, the angles at C and A are together equal to one right angle.

When the foot of the tower is inaccessible, the angle GFE is measured, then the space FD and the angle FDE; the angle EFD is found by subtracting GFE from two right angles, since every straight line falling on another straight line forms with it two angles, together equal to two right angles. But when the angles D and F in the triangle EDF are known, the angle at E is easily found by subtracting the sum of the angles D and F from two right angles. But as a general rule in Trigonometry, when out of the three sides and three angles of a triangle, any three, except the three angles, being given, the remaining three can be determined. Hence the length of the line A B in the triangle ACB, or the height of the tower, can be so discovered; and in the triangle FDE the length of EF can be discovered, as preliminary to the same steps.

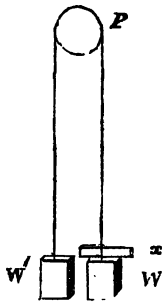


Motion.—The laws of motion, which make up so important a part of Natural Philosophy, stand at once on a different footing from mathematical truth, and from the principle of gravitation. It is common to enumerate three laws of motion. The first is, that a body under the action of no external force will remain at rest, or move uniformly in a straight line. The second, that when a force acts upon a body in motion, the change of motion in magnitude and direction is the same as if the force acted upon the body at rest. The third law of motion is, that when pressure communicates motion to a body, the momentum generated in a given short time is proportional to the pressure, or, as given by Newton in a more general form, action and reaction are equal and opposite.

In order to form a correct notion of these laws, we must have definite ideas of bulk, force, velocity, motion, and pressure, as well as the modes of measuring them. Newton defines the mass of a body to be the product of its density and its volume; and he determines the mass by its weight, because he found, by most accurate experiments with pendulums, that the mass is proportional to the weight. We see that all bodies placed above the earth's surface have a tendency to fall, and exert a force upon whatever support prevents them from falling; this force we term pressure, and the measure of this pressure is weight—bodies being said to be of equal weight, if they produce equal pressure on their support; consequently weight is a measure of the earth's attraction for heavy bodies; but, in assuming weight to be a measure of mass, or the quantity of matter contained in a body of given volume, we clearly assume that the earth's attraction is the same for all kinds of matter; and that a cubic inch of gold weighs more than a cubic inch of copper, because the former contains more particles of matter than the latter, and not because the earth has a more powerful attraction for gold than copper—an assumption abundantly confirmed by experiment. Hence weight becomes a measure of pressure, and consequently of force producing pressure. We can also estimate force, in another way, without reference to mass, pressure, or weight. According to the first law of motion, a body can only move by the action of some external force; now, the space through which it passes in a given time will afford us a measure of its velocity, which is only a term for the quickness or slowness of its motion; and the velocity acquired in any given time will afford us a measure of the force which produces the motion of the body. Neglecting the resistance of the air, it is found that all heavy bodies, how different soever in weight, fall through the same space, and acquire the same velocity at the end of any given interval of time. It is clear, therefore, that the measure of a force, by the velocity it generates in a given time, in no way involves any consideration of the mass, and must therefore differ from our previous measure of force.

Force, measured by the velocity generated in a given time, is called accelerating force; force, measured by weight or pressure, is termed moving force. Now, though we can conceive, as a consequence of what we have said, that two equal accelerating forces, acting separately on two different masses, would cause them to acquire the same velocity, at the end of a given time, it does not follow that these different bodies would produce the same effect on any body which might oppose their motion. In order that they should do so, it is necessary that the product of the mass and the acquired velocity, should be the same for both moving bodies. Thus a ball of 2lb. weight, moving with a velocity of 50 feet per second, will cause a ballistic pendulum, when struck by it, to vibrate through the same arc as when struck by a ball of 50 lb. weight, with a velocity of 2 feet per second, or a ball of 100 lb. with a velocity of 1 foot per second. The product of a body's mass, and its velocity, is called its momentum, or quantity of motion.

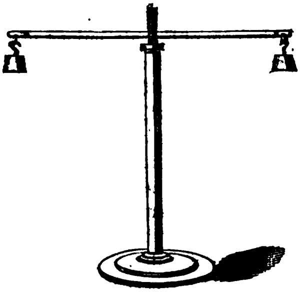
If we conceive two equal weights, W and W′, suspended from the extremities of a string passing over a pulley P, supposed to be destitute of friction, the weights will remain at rest. If we place ever so small a weight, x, on the weight W, the weight on which we place it must immediately descend; and, as long as x is placed on W, by the first law of motion, the velocity of its descent will continually increase. If we remove x the weight W will still descend, but with the velocity constant, which it had acquired at the instant of x's removal. Now in this case the weight x is called the moving force, or pressure producing motion; the two weights W and W′, together with x, the mass moved: the velocity of W's motion will be a measure of the accelerating force produced by x. Now it is found, by numerous careful experiments, that this accelerating force, multiplied by the mass moved, $2W+x$, is always proportional to the pressure-producing motion x: and this is the third law of motion.



The laws of motion cannot be proved by any series of experiments, however extensive—these experiments only suggest the laws; and perhaps our firmest conviction of their truth arises from the wonderful manner in which, by combining these laws with the principle of gravitation, Astronomers have been able to predict the motions of the heavenly bodies with such marvellous exactness, and even to point out with certainty the precise spot in the heavens where a planet hitherto unknown would be found. To some minds these laws may appear objects of intuitive belief, when once we have acquired correct ideas of matter, force, and motion; but on this point some metaphysical difficulties clearly exist. Our natural belief in the laws of motion certainly differs from that which prevails in regard to mathematical truths; for the opposite of mathematical truths at once presents a contradiction, while the opposite of the laws of motion may not exhibit itself at first as a contradiction to every mind.

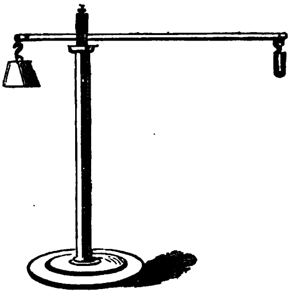
Moreover the human mind cannot conceive that even Omnipotence can make two and two anything but four. Nevertheless, if we contemplate a heavenly body at perfect rest, on the assumption that it is for the time the only body in space, that heavenly body, in the language of the first law of motion, will remain at rest for ever, unless some cause of motion come into operation.

In this case who will dare to say that it is impossible for Omnipotence to move that heavenly body without applying a cause of motion? Such an assertion would be wholly inadmissible, unless, among the causes of motion, it is understood that the Fiat of the Almighty is included.



The Balance.—The principle of the Balance seems at first sight self-evident; for it is self-evident—at least to a person of ordinary intelligence—that if a rod of uniform material and dimension be fixed by its middle point on a pivot, and two bodies equal in weight be suspended one from either extremity, they will be in equilibrium. But to render this proposition intelligible, the nature of gravity, as a property of bodies at the earth's surface, must be clearly seen.

That being understood, the proposition will then stand thus:—Equal causes, applied exactly in the same manner, must produce equal effects; the causes being the like number of particles tending downwards on either side of the fulcrum. And, by an easy demonstration referable to self-evident principles, it can be shown that when the weights differ, there is, nevertheless, an equilibrium, if the fulcrum be at the point in the rod which divides it inversely in the ratio of the weights.



This case, however, plainly differs from the convictions afforded by the necessary truths of mathematics, since the reasoning is mixed up with principles ascertained by experience,—the gravity of bodies, for example. And the same thing may be said of the demonstrations respecting the mechanical powers in general,—the lever, the wheel and axle, the pulley, the inclined plane, the wedge, and the screw.

In Hydrostatics it is self-evident that a solid and insoluble body, immersed in a liquid, must displace a quantity of the liquid equal to its bulk. The discovery of this fact cost Archimedes a great effort; but the moment it occurred to his mind, it was self-evident, and required no proof to obtain universal assent. That a solid floating body, like a ship of the line, displaces a quantity of water equal to its weight, is equally true, but not, at first sight, quite so obvious.

The refraction of light, to which so many phenomena can be referred, admits of no explanation. The evidence of the truth of this law is as yet derived solely from observation; and a wholly opposite condition of the law could be as readily received upon the same evidence as its actual form.

Gravitation.—The law of Universal Gravitation rests ultimately on observation. It is the greatest achievement of Inductive Science. It is expressed in the language of Mathematics; but it has nothing of the character of a mathematical truth. This law declares the mutual gravitation of all bodies, with forces directly as their quantities of matter, and inversely as the squares of their distances.

In the expression of this law bodies are conceived to consist of minute particles, more or less closely aggregated or packed together. In Physics, all such component particles of matter (differing from the laws on Chemistry) are regarded as made up of the same small portions of matter; that is to say, it is a part of the law that any two particles, at whatever distance from each other, exert the same mutual attraction. Thus the attraction of one body or mass of matter for another is the sum of the attractions of all the particles of the one towards the sum of all the particles in the other; and if the attraction be equal on both sides, that is, if the attraction exerted by the one be as great as the attraction exerted by the other, it is determined in the abstract, that the number of particles in the one is exactly the same as the number of particles in the other. But these two bodies, which are thus conceived to contain equal quantities of matter, may be either of the same magnitude, or may considerably differ in magnitude. A cubic foot (that is 1728 cubic inches of water,) contains no more matter than 128 cubic inches of mercury, which is the same thing as to say there is the same number of particles of matter in 128 cubic inches of mercury as in 1728 cubic inches of water.

The Law of Gravitation is expressed in its simplest form, as respects particles of this kind—namely, the particles of matter attract each other inversely as the squares of their distances. For example, to make the violent supposition that there is previously no matter in the universe, let two particles of matter be called into existence, and observed first at the distance of five miles, and then at three miles from each other. Their attraction for each other is greater at the distance of three miles than at the distance of five miles; but the greater attraction is not represented by 5 and the less by 3, but by the squares of those numbers, that is, by the one and the other of these numbers multiplied each into itself, the products of which multiplication are 25 and 9. Thus the attraction between these two particles at five miles' distance is represented by 9, and at the distance of three miles by 25. The law does not indicate the velocity with which two such particles will approach each other; but did we know what proportion each bore to the whole mass of the earth, then it might be discovered by reference to the velocity of bodies falling near its surface—sixteen feet in the first second.

We may here remark how the laws of motion mix themselves up with the law of gravitation,—the same supposition being continued as to the absence of all other matter in space. If, after these two particles had approached to within three miles of each other, one of them were annihilated, all attraction would of course cease; but the other particle, in accordance with the first law of motion, would continue to move onwards in a straight line with the velocity which it had acquired at the moment of the extinction of the other.

Attraction.—To express the attraction exercised by the particles of the sun over the particles composing each of the planets, numbers must be fixed upon which express, in some kind of dimension, the distances of each of these from the sun, and these numbers being squared we shall obtain a series denoting their relative attractions. To keep down the number of figures, it is best to choose some large measure, for example, the distance of the moon from the earth, or 240,000 miles.

In the following table are set down the squares of the distances of the old planets from the sun, expressed in numbers, denoting how many times each planet is more distant from the sun than the moon is from the earth.

Mercury	25,600	Jupiter	4,410,000
Venus	78,400	Saturn	12,960,000
The Earth	160,000	Uranus	57,760,000
Mars	360,000		

These numbers, however, do not express the actual attraction between the sun and these several planets; but only what their relative attractions would be, if each contained the same number of particles. But where an estimate is already formed of the quantity of matter in any planet, and that quantity is considered in connection with the estimate of the quantity of matter in the sun, and the actual velocity in bodies falling near the surface of the earth, then the elements are afforded for calculating the actual force of gravity between the sun and that planet. The roots corresponding to the numbers in the above table denote the actual distances of the planets from the sun, as measured by the distance of the moon from the earth,—namely, for Mercury, 160; for Venus, 280; for the Earth, 400; for Mars, 600; for Jupiter, 2,100; for Saturn, 3,600; for Uranus, 7,600; or nearly as 1, 2, 3, 4, 15, 28, 54.

It is easy to see that the law of gravitation is sufficiently stated, when made to refer to particles of matter, by simply saying that the particles attract each other inversely as the squares of the distances. For it follows, as a necessary consequence, when a number of particles are collected into one mass, and a lesser number of particles into another mass, that the sum of the attractions in the one shall be to the sum of the attractions in the other, directly as the number of particles in the one, is to the number of particles in the other. Again, when two bodies of the same bulk exhibit exactly the same attraction the one for the other, and under the same circumstances, we conclude that the number of particles in each is the same; and this is what is signified when it is said that two bodies have the same density. Moreover it can be proved that the attraction between the centres of two spherical masses of matter is the same as if the whole particles of each mass were collected within their respective central points.

The attraction between two bodies, or masses of particles, is measured, not by the mere velocity acquired by each, but by the amount of motion, or the momentum which each exhibits. When two masses of matter, different in the number of their particles, are supposed to come into existence in free space at some distance from each other, the quantity of motion produced in each is the same. That which contains the greatest number of particles would move with less velocity; that which contains the less number of particles with greater velocity; but the momentum, or quantity of motion, in each will be the same.

It is easy, then, to understand, on the principle of gravitation, why two bodies—for example, a pillow and a piece of lead equal to the pillow in weight—were there no atmosphere, would fall to the ground from a given height in the same time. Both would have the same momentum: but the momentum or impulse of the piece of lead would be impressed on a small portion of the surface, while that of the pillow would extend over a large surface, so that each point of that surface would be less affected.

At first consideration, it may be somewhat difficult to see clearly that this great law of gravitation essentially differs from a mathematical proposition, as resting not on intuitive convictions but on observed facts. But a closer view of the whole subject satisfies the inquirer that no law of this kind could have been predicted *à priori;* that is, from any natural or intuitive conviction of the human mind. Such knowledge has no other foundation than observation. What confuses the mind is the large extent to which mathematical investigation is employed for the assistance and perfection of observation. Here, however, mathematical investigation serves merely the office of an instrument, by which, indeed, the dominion of the senses over nature is almost immeasurably increased.

Physics.—The several subjects just noticed fall strictly under the head of Natural Philosophy or Physical Science, and indeed merely afford examples of the kind of knowledge which belongs to that great department. But when we consider that Natural Philosophy is ancillary to the great objects of Mechanical Science—to the construction of Time-keepers, the Hydraulic Press, the Steam Engine, Artesian Wells, Gunnery, the Pendulum, Telescopes, Microscopes, the Barometer, the Tides, Railways, &c. —we shall be able to estimate the vast importance of a knowledge of its various subdivisions to men, particularly to those living in countries newly settled, and where the division of labour has not yet been carried sufficiently far to save every man from the necessity of being his own engineer and overseer. Even in the long-established social communities of modern Europe, we have but to glance the eye over the career of individuals of great activity of mind rather than of solid education, to discover how much time and money are annually wasted in the vain hope of accomplishing what is unattainable. Many a man of genius in former times, unenlightened by the knowledge this Work is intended to convey, has wasted his life and fortune in fruitless efforts to discover the perpetual motion. And although this is not often now the object to which uninstructed ingenuity is directed, there is still as much health, as much genius, as much industry, as much wealth consumed on things unattainable as in former ages.

Electric Sciences.—The fact that amber, after being rubbed upon woollen cloth, first attracts light bodies and then repels them, and upon which the Science of Electricity rests, derives all the evidence of its truth from observation. The same may be said of all the discoveries hitherto made in Electricity. There is no principle in the whole subject which could have been inferred independently of observation. It is purely a science of induction; and the same remark may be made of Galvanism. It was as impossible to predict, *à priori*, the decomposition of water, and the other surprising effects of Galvanism, by the mere approximation of two metallic plates immersed in an acid solution, as it is to establish, *à priori*, after the effect is witnessed, that it is really due to the apparatus employed. Of Magnetism, what more can be said than that certain facts have been ascertained by observation? And although it is now sufficiently apparent that Electricity, Galvanism, and Magnetism are merely different forms of one more general science, that conclusion has been deduced, not from any *à priori* reasoning, but simply from the accumulation of facts, and the inference of principles from these by the common process of induction.

Under the heads just noticed, together with those of heat and light, how many subjects fall, of surpassing interest and of the most direct use to men in every situation of life! Some years ago, when the number of steam-boat accidents in the United States attracted public attention, an American writer successfully showed that as many persons every year lost their lives by lightning, within the Union, as by the bursting of steam-boilers. Increased knowledge and attention on the part of engineers have very much diminished the annual mortality from steam-boat accidents; and surely it is not too much to expect that the great annual loss of life by lightning may be materially circumscribed by a better acquaintance with the nature of the electric fluid, and the precautions which such a knowledge may suggest for avoiding danger during the violence of a thunderstorm.

Chemistry.—But Chemistry supplies the best example of a purely inductive science; and the progress which Chemistry has already made is sufficient to make known the final composition of the bodies which man sees on every side around him. It teaches that, out of sixty-three simple substances, all these bodies are constituted. It shows him how to obtain each of those simple substances in a state of purity; and, when it is required, it points out how these simple substances are to be converted into such compound bodies as are necessary to the arts and conveniences of life.

In Chemistry there are no original *à priori* rules. There are no facts or laws discoverable by the mere light of thought, independently of experiment and observation. All that the exercise of genius can do in Chemistry is to suggest new paths to be explored. Chemistry, therefore, is a science which enables us to understand both the extent and the limits of the Baconian precepts. It is wholly inductive; and yet the principles which induction has here afforded, while they are numerous and most available, are, as laws of nature, neither free from exception nor very comprehensive.

It is by the study of the mere properties of substances that chemists have achieved most of their success. The early progress of Chemistry was tardy in the extreme, until gaseous bodies fell under rigid examination; and from that date its progress has been almost incredible. Chemists for ages knew of several sorts of air; but they seem never to have arrived at the idea, that by determining the several peculiar properties of these airs they might be able to distinguish them from each other. Hydrogen gas has been known from time immemorial as an inflammable vapour, which played about the apparatus whenever sulphate of iron was directly made by the addition of dilute sulphuric acid to iron filings. But although its peculiar inflammable character was known, and even its smell in this way of producing it, and also that it did not appear unless a large proportion of water was added to the acid; yet no one thought of seeking the means of identifying it when otherwise produced, until Cavendish noticed its extreme levity.

There was no deficiency of genius or industry among chemists during the period of this slow progress; but with all their solicitude to pursue the precepts of Bacon, they do not appear to have sufficiently felt the necessity of an exact knowledge of the peculiar properties of every substance, and the means of its identification when present in minute quantity. The only efficient aid which chemistry has derived from exact knowledge is the homely aid of the balance. Until recently, chemical operations were too rude to admit of much advantage from the nice determination of the weights of the substances employed in experiments; otherwise, how many difficulties of former times might have been solved without delay!

In the experiment of burning hydrogen gas with oxygen gas, it was remarked, at an early period, that the apparatus became bedewed with moisture. The gases shrank into nothing, and moisture was found upon the apparatus. Yet it was a long time before the conclusion was drawn, that the water was the product of the combustion. The balance would at once have settled this point, by showing that the water produced equalled the sum of the weights of the two gases exploded.

The subjects which Chemistry embraces are so many necessities of man in his social life. A few examples of the departments of art founded on Chemistry will suffice to show how desirable a knowledge of Chemistry is to every man, whatever his occupation in life. Among these stand prominent the extraction of metals from their ores; the subject of artificial light, or the various modes of artificial illumination; the arts of dyeing and bleaching; the substances fit for fuel; the nature of fire-damp and choke-damp in mines; the artificial production of ammonia, in reference to agriculture; gunpowder; artificial minerals; chemical tests, and the detection of poisons; ventilation, and disinfecting agents; cements; artificial minerals; pigments; metallic alloys; and other subjects which it is needless here to enumerate.

Physiology.—Next in order to Chemistry stand the Physiological Sciences. The discoveries in this science are to a great extent peculiar laws of nature, while many of the phenomena of living bodies are physical, chemical, and electrical. When the muscular fibre shortens itself on the application of a stimulus, it is in obedience to a pure Physiological law. When the impression conveyed from the surface of the body by a reflex nerve is succeeded by an influence transmitted to an organ of motion, it is in obedience to another distinct physiological law.

Certain laws of nature acting together with the laws of motion produce the planetary movements, so strikingly remarkable for symmetry and harmonious union with each other. On the other hand, certain laws of Physiology, in apparent opposition to the laws of physical nature, and to the ordinary laws of Chemistry, produce effects in every way so surprising, as to have engaged the attention of men in all ages, upon the very peculiar nature of the influences by which such effects can be called forth and sustained with an almost unerring uniformity, during the various limited periods to which the existence of individuals in the two organic kingdoms extends.

There is nothing, in the whole character of physiological science, more at variance with the general economy of nature than the limited duration, in each individual, of the phenomena which constitute animal or vegetable existences;—and the complete isolation, throughout its whole existence, of each individual from other portions of the organic world, after the first separation from the parent organism, is another most striking and peculiar feature of physiological science. The innumerable forms which organism assumes, in the varieties of animal and vegetable species, set at nought every possible idea of their source being a mere physical force of development, under the limitation of a few overruling influences. And what is not less remarkable than the characters already stated, is the manifestation, at every step, of the nice accommodation of means to peculiar ends, in the structure and economy of organic bodies, which renders it impossible to seize the mere inductive laws of Physiology, without a perpetual reference to final causes.

If it be said that the animal or plant could not have existed without certain organs adequate to certain ends—and therefore that such contrivances are merely indispensable conditions of existence,—the answer is, that organic nature is not a necessary part of the economy of the universe; that the material world, without the organic, was complete in itself; and therefore it is to be concluded, because the organic world exists with marks of design, such as characterise the works of man on earth, as distinguished from the works of nature, that in the origin and maintenance of the organic world there is manifested a special intelligence and wisdom, without continual reference to which Physiology will fail to make the progress of which it is susceptible.

The knowledge of Physiology opens up a new field of human thought. In it we trace the wisdom of the Creator, as in Astronomy we discover manifest proofs of his power. Galen said with truth,—"The study of Anatomy is the use of a hymn in praise of the wisdom of God." This is, indeed, the most dignified office of Physiology; and it is in this light that it exhibits its greatest glory. But to how many subordinate uses is it also subservient! Under Physiology, in its largest sense, stand Medicine and Surgery. In proportion as the knowledge of even a rude Physiology has diffused itself, has the value of human life increased. Both Medicine and Surgery are but handmaidens of Nature; but how ineffectual—nay rather, how pernicious—were man's natural modes of treating diseases and injuries, until the knowledge of Physiology had enlightened him. One great use of a knowledge of Physiology is to teach men what they should avoid doing when diseases have arisen, or injuries have been sustained. He who understands something of the animal economy, knows with what precaution he should employ less known remedies; while he knows also, that even good remedies are only good when seasonably used. And this knowledge, so far from unfitting him for finding new remedies among the natural productions of a strange place, affords him an infinite advantage over every one who, without such knowledge, ventures to experiment upon a disease. Let a man understand the general scope of Physiology, and he becomes, under sickness or injury, a safe guide in the wilds of Australia; while he who is ignorant of the animal economy, if he uses remedies at all, uses them as much at random as in the days of spells, amulets, and charms. If he has studied Botany, he knows, as we shall presently see, from which families of the vegetable kingdom safe drugs may be taken, and from which poisonous substances may be feared.

Man, in every country, acquires the most part of his knowledge by experience; but in every complex kind of knowledge, like that which relates to man, animals, and plants, his experience deceives him, unless he be previously acquainted with the general scope of nature in that department. Hence a new settler in a strange country, who understands Physiology, has an immense advantage over one whose ignorance does not allow him to interpret the things which daily come under his notice.

Psychology.—The vast recent progress of the physical sciences has cast into shade those important branches of knowledge which rest on thought retroverted upon itself. Such are the Psychological sciences,—Metaphysics, Logic, Ethics, etc.

However little has been the progress of an exact kind hitherto made in those sciences, there can be no doubt that man is both capable of making, and destined to make, great advances in those all-important departments of knowledge. If it be asked to what end? The answer is, that it is solely by the general diffusion of these sciences that language can be made an exact medium for the interchange of thought and opinion on all subjects which are not represented by sensible objects.

In no distant time the activity of mankind must require new occupation of mind. The career of physics, astronomy, and chemistry, must begin to slacken, if such a slackening has not already commenced. The world at present stands amazed at the successful application of the discoveries, not quite of recent date, in the physical and chemical departments, to the arts of life—steam navigation, gas illumination, railway communication, the electric telegraph, the advance of agriculture; but even these wonders must lose their novelty, and the time will arrive when the sciences of mind will have their turn of popular favour and cultivation, from which the most important fruits may be anticipated.

The stagnation of the psychological sciences extends to all those which rest upon moral evidence; in short, to all those which depend for their progress on precision of nomenclature, while the subjects of inquiry are not fully represented by sensible objects. There are, indeed, numerous departments of human knowledge which seem to depend on mere observation, in which general principles are continually deduced from apparent facts, while the progress made is very little commensurate with the labour bestowed upon them. This defect of progress arises chiefly from the so-called principles or inferences being deduced from particulars called by the same name, without being, as is necessary for a perfect induction, exactly identical in character. The Science of Government, the Science of Law, the Science of Medicine, and many other departments of human knowledge, come within this description.

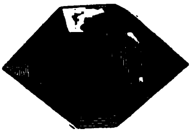
Statistics.—Statistics have of late assumed the character of a separate branch of knowledge. It is rather an art than a science; and, when unskilfully practised, is subject to the greatest possible fallacies in its deductions. The evidence of statistics is apt to be represented as equivalent to that of demonstration. But the slightest consideration will show that the evidence of statistics, though capable in some circumstances of being demonstrative, also ranges through every degree of moral evidence—the possible, the probable, and the morally certain. Hence the source of the great errors just referred to, as often as the evidence of statistics is assumed to possess one uniform demonstrative character. It is manifest that in all kinds of induction the principles arrived at can have no higher authority than the evidence bearing on the identity of the several particulars out of which these principles have been drawn.

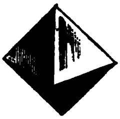
It seems unnecessary to go farther in illustration of the proposition that the various departments of knowledge, resting on moral evidence, cannot make effectual progress until the psychological sciences have gained a larger share of popular favour, and have become generally cultivated and understood.

Natural History.—Between Natural History and the descriptive sciences, a strict alliance has been closely cemented. In the advantages of this alliance both departments participate. Natural History was originally very rudely arranged, owing to the various mineral, vegetable, and animal species being grouped together, in accordance merely with their most obvious external characters. What are termed natural systems of Natural History have arisen out of its alliance with the descriptive sciences,—the knowledge of the minute structure of plants and animals, and of the structure and composition of mineral bodies being made subservient to the grouping together these individuals of the three kingdoms which are most closely related to each other in internal as well as in external characters.

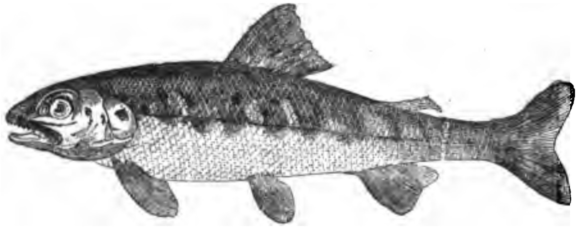
Mineralogy.—What a field of profit to the student does Natural History present! In the inorganic kingdom, how precious is the knowledge by which he can, figuratively at least, convert dross into gold. If a man has become acquainted with the characters of mineral substances, he may discover that which is regarded as worthless to be often of the greatest value for some purpose in the arts. A recent action at law exhibited one of the parties as having obtained a lease for upwards of twenty years of a coal-mine,—one of bituminous shale, which yields many times the price of coal for the manufacture of gas. The lease was found valid. Now, had the proprietor known a little of mineralogy, instead of entering upon a costly law-suit, he might have enriched himself by selling his own stratum at its actual value. But numerous instances could easily be cited, in which similar ignorance of natural objects is tantamount to loss; and where, on the other hand, even a slight knowledge leads to great pecuniary benefit.

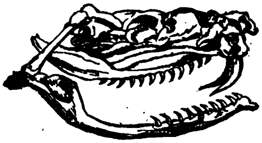
Knowledge of the Mineral Kingdom implies an acquaintance with the characters by which the precious stones are recognised; with the indications of the mineral forms of the useful metals; with those of marbles, spars, alabasters, and ornamental minerals in general; with building stones, and their relative value; and with the minerals which characterise the several geological formations. All these subjects we propose to introduce in due time into our Treatises; and on how many occasions may our expositions of this description of knowledge prove of the utmost service in many positions of life! Let us state a case, as related by Professor Tennant in his Fifteenth Lecture, on the results of the Great Exhibition. For want of the knowledge of the crystalline form of the diamond, a gentleman in California offered £200 for a small specimen of quartz. The gentleman knew nothing of the substance, except that it was a bright, shining mineral, excessively hard, not to be touched by the file, and which would scratch glass. Presuming that these qualities belonged only to the diamond, he conceived that he was offering a fair price for the gem. The offer was declined by the owner; who, had he known that the diamond was never found crystallized in the form of a six-sided prism, terminated at each side by a six-sided pyramid, as seen in the larger cut, which is the exact size and shape of the stone, he would have been able to detect the fact, that that for which he was offered £200 was really not worth more than half-a-crown! The larger figure represents the piece of quartz in question; the smaller, one of the more common forms of the diamond.

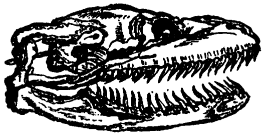




Zoology.—Again, as to the Animal Kingdom, how large the mine of knowledge it embraces, and that of interest and importance not confined to the naturalist! The merchant, the manufacturer, the agriculturist, the traveller, the sportsman have all to seek aid, in their several pursuits, from a knowledge of this department of natural history. Look to the value of our fisheries, and judge how available to the commercial world becomes this knowledge of animal nature. Nay more, but for our knowledge of natural history, one of our most important articles of food would in time have entirely disappeared from our waters. We allude to the salmon, the fry of which, and the parr, are now universally acknowledged to be identical. Our cut represents the fish so well known by the transverse dusky bars which mark its sides. Under the name of parr, it abounds in all salmon rivers; and, until the researches of Mr. Shaw, Sir Wm. Jardine, and others, proclaimed it to be the young of the salmon, it fell in thousands before the strategies of every village boy who possessed a crooked pin and a yard or two of line. Science has now established its value, and invoked regulations for its preservation. The angler, too,—how much more successful is he in his sport who has studied the circumstances which influence the humours of his prey? Is it less true of the sportsman who unweariedly paces the moors in autumn that his success is intimately dependent on his knowledge of the habits of the game? The wild-goose chase is proverbial; but, besides the actual chase of the bird, in which no one succeeds who does not understand its habits, there are many figurative wild-goose chases in the animal kingdom in which success fails from ignorance of particulars, which the study of Natural History could easily have supplied. A practical illustration of the benefits even of a slight knowledge of Zoology, presents itself in the case of a traveller or emigrant in some unknown country. He has pitched his tent, or raised his hut; and then he finds the locality infested by serpents. He is all anxiety and fear. He knows not what to do; whether to proceed to another spot, or to remain and brave the danger. Some acquaintance with the structure of reptiles would at once have decided his plans; for with the first he killed he could decide whether they were venomous or harmless. The former—and the common viper is one—possesses, on either side of the head, glands which secrete their venom; and, to conduct it to the wound they inflict upon their prey, they are furnished with two hollow but long, recurved, and sharply pointed teeth in their upper jaw. The harmless serpents have no such apparatus; and thus the two genera are at once distinguished by the absence or presence of the fang in question. Our cut, after Professor Owen, exhibits the skulls of the two families with their dental peculiarities.







Botany.—A treatise might be written on the benefits which an acquaintance with the Vegetable Kingdom is capable of affording. Of how great use is it in strange countries to be able to distinguish the plants fit for food, from such as are poisonous; and to recognise those which have been employed in medicine, or in any one of the numerous arts to which the Vegetable Kingdom is subservient. Even an Elementary knowledge of Botany is of exceeding interest and importance. Travellers in unknown lands know full well that life or death often depends upon their acquaintance with the science—an acquaintance, it may be, not derived from learned treatises, but simply from little more than the ordinary observation of those edible plants with which all persons are familiar. But even this is still a knowledge of Botany. An all-wise Providence has so arranged that plants may be associated into families from their external resemblances; and, further, that plants possessing such resemblances to each other, have many properties in common.

One of the great families of plants is the Cruciferæ, or Turnip tribe, every member of which, marked by very obvious characters, is easily recognised, and scarcely to be mistaken; and all are remarkable for edible and antiscorbutic properties. The crew which accompanied Vancouver in the expedition of 1792, suffered severely from scurvy, from want of vegetable food. The surgeon advised that they should make for the first land; and at Cape Horn he found a plant, resembling spinach, which he directed to be used as food, with the happiest effects. This is not a rule without an exception; but it is of such universal application that the traveller may, in his necessity, safely trust himself to its guidance.

The Icosandrous plants, or such as have an indefinite number of stamens attached to the calyx, are remarkable for their fidelity to this law. They are all edible, and are represented by the apple and pear tribes, the cherry, the strawberry, &c.

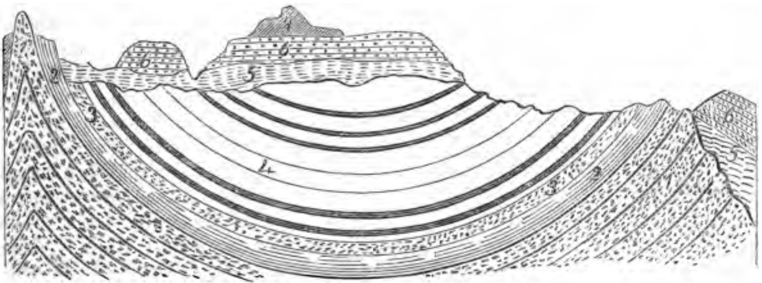
There is also another great family—the grasses, the members of which exceed those of any other class, in number and in their essential importance to the whole animal creation. This family comprehends the grasses, commonly so called—the wheat oat, barley, rye, &c.—of our temperate climate, and the sugar canes of tropical regions; and all possess the common properties of being nutritious and healthful. During Lord Anson's voyages, on the failure of provisions, the mariners landed and found vegetables, which, although unknown, were recognised as belonging to this great family, and proved to be highly beneficial.

But while the value of this law is indisputable, a further knowledge of Botany is necessary to the traveller; since he will frequently find associated together edible and poisonous plants. Thus, the deadly Upas Tree is placed with the delicious fig. The magnificent Euphorbias of tropical forests yield, on the one hand, the refreshing juice of the E. Balsamifera of the Canaries, and the Yuca Dulce, the nutritious farinaceous meal of Mexico; and, on the other, furnish to the warlike inhabitants of Ethiopia the poisonous juices in which they dip their arrows.

The splendid Cactuses, also, produce the delicious milk of the Hya-hya, in British Guiana, and that of the Cow Tree in Ceylon, and also furnish the strychnine of medicine, and the far-famed wouralie poison of the banks of the Orinoco. Lastly, it frequently happens that, while one part of the plant yields an article of food, another is laden with noxious properties. Thus, if the starch furnished by the Euphorbias and Cactuses were eaten before the juices of the plants were expelled, speedy death would ensue; and, as a more familiar example, the tubers of the potatoe plant form a valuable article of diet, while its green-coloured fruit is poisonous.

Geology.—Geology, again, is no longer a merely curious speculation. On the contrary, it is one of the sciences which most surely leads to practical results. It has methodised the crust of the earth, and taught us to look for certain minerals almost as we look for certain books upon certain shelves of a library. Coal is nowhere found but in the coal-measures; and a knowledge of the position of the coal or ironstone strata, and of the rocks usually associated with them, has guided the capitalist to the spot where he might engage in the search for these products with the least chance of disappointment; and in many instances, had the directions of Science been sought and followed, vast sums would have been saved to the community.

Deceived by appearances, or misled by designing individuals, persons have sought coal at a great expense in the wealden formation of Sussex, the oolites of Oxfordshire and Northamptonshire, and among the silurians of Radnorshire; whereas attention to the simplest principles of Geology would have shown the folly of such attempts. Because Pennsylvania is rich in coal, it was imagined, in the neighbouring state of New York, that the precious gift might also be found there; and the resemblance of certain silurian rocks, on the banks of the Hudson, to the bituminous shales of the true coal formation, appeared to sanction the surmise. Accordingly mining adventurers squandered away a large amount of capital; until Geology, at the invitation of the Legislature, authoritatively declared the futility of the attempts.



1. Old Red Sandstone. 2. Mountain Limestone. 3. Millstone Grit. 4. Coal Measures.
5. New Red Sandstone. 6. Lias. 7. Superior Oolite.

Our cut exhibits a section of the Great Bristol Coal-field, extending from the Mendip Hills to the north-west of Bath, a distance of about twenty miles.

Arrangement of Knowledge.—Besides the Sciences and the Liberal Arts, which last will obtain a due share of our attention, there are, among the subjects of human knowledge, the Arts and Manufactures, which contribute to the convenience and comfort of life; and which may be classed under the general head of Social Economy.

The various branches of knowledge of a practical kind connect themselves with corresponding branches of Science. Some arts are mechanical; some chemical; some physiological, and some purely intellectual. In all these departments there are practical branches of knowledge which deserve the attention of every one who desires to be accounted liberally educated; while there are others too technical to admit of any proficiency except on the part of those who devote their lives to the pursuit. Arts of this latter description will not enter into our plan; but, in other respects, we shall exclude no branch of study which belongs to the education of an accomplished citizen.

It is thus seen that the mode in which we design to treat our subjects is such as best conduces to exercise and improve the human faculties, and to open and expand the mind.

Uses of Knowledge.—The acquisition of knowledge has two great objects; namely, to obtain information for its own sake—that is, for the sake of the uses to which that information may be applied; and also, by the varied exercise of apprehension, memory, reasoning, judgment, and other powers of the intellect, to render those faculties available for the purposes, however great, in which, one time or other, a man's position in life may require their utmost service.

The effect of education upon the individual is easily understood. It makes him what he actually is, as respects the particular stores of knowledge he possesses, and the command of mind which he can bring to bear on every crisis of his life. But man in society does not stand insulated, either as respects his knowledge or his powers of exertion. Every man possessed of knowledge and of ability, natural or acquired, sheds around him gifts of incalculable value. He is a centre or focus from which light is diffused on every side. A person who is himself uneducated, by living among those who are educated, obtains no small share of the advantages which they possess. He picks up fragments of their knowledge; but by far the greatest of his gains arises from the circumstance that, by the imitative power with which our species is so largely gifted, he catches the spirit of the acquired modes of thinking possessed by those around him; so that, although his knowledge may remain rude and disjointed, he begins to think like one who has received a liberal education. Thus, like charity, knowledge carries with it a double blessing—blessing him that offers, and him that receives.

Perhaps no people as a body ever exceeded the Athenians in acuteness. This we may justly infer from the style of the orations addressed to them, particularly from the stern, direct character of those of Demosthenes. To the immediate education of the Athenian youth no very great attention appears to have been paid. We are told that their first instruction was in swimming and the rudiments of literature. As for those whose abilities were but mean, they were to learn husbandry, manufactures, and trades. Those who could afford the education of a gentleman were to learn to play upon musical instruments, to ride, to study philosophy, to hunt, and practise gymnastics. Whence, then, did the Athenians as a body acquire that reputation for acuteness, for which undoubtedly they were pre-eminent? The portion of the people to which this character applied, probably at no period exceeded thirty thousand, if, indeed, that be not too high an estimate; since it only excludes the servants and bondmen, by far the most considerable proportion of the inhabitants, and makes allowance for about ten thousand foreigners, who were permitted to listen, but not to take part in public affairs, or in public amusements.

The signal acuteness of the Athenians arose, unquestionably, not from any remarkable superiority in their early education, but from the public life which they lived, continually listening, in their public assemblies and courts of justice, to orators; in the schools of philosophy, to discourses on human nature rather than on physical science; and in the theatres, to the unrivalled dramas of their tragedians and comic writers. Thus an Athenian, when Athens was at the height of its fame, could not be otherwise than acute. He took part in the deliberations regarding public affairs; he was present whenever instruction or amusement was going forward; and, if war arose, he fought,—sometimes by sea, sometimes by land. He had occasion for no language but his own; his instruction was chiefly oral; he required no books but those written almost in his own time; and he could not but know his own language in all its minuteness and shades of meaning. He was a statesman, a legislator, a lawyer, a soldier, a philosopher, and a man of taste; he was therefore master of all the technicalities which had as yet arisen in the language; and nothing could be spoken of, or even hinted at, which he did not at once perceive and understand.

How different is the case in modern times! How much more must be learned to be on a level with the age than was necessary in Athens! At Athens the knowledge and acuteness by which an accomplished citizen was distinguished, came to him as easily as an acquaintance with town life now comes to those hopeful scions who spend their nights and days in the metropolitan streets.

We cite the superior acuteness of the Athenians to illustrate the effect of the spread of intelligence from mind to mind, by which the improvement of a small proportion of the population becomes a sort of leaven to the whole mass, which, under favourable circumstances, may quickly become similarly affected. But the history of the Athenian people affords us another lesson, by showing how much the world has changed since their time, and how much more laborious is now the task of acquiring knowledge, and a character for intelligence and acuteness; for, in our day, owing to the rapid extension of new departments of knowledge, and the consequent increase of new terms, there is no longer that general acquaintance with the meaning of words which prevailed among the ancient inhabitants of Athens.

Popular Errors.—We admit that, in the course of time, society, merely by having included within it a small sprinkling of persons imbued with exact knowledge, has come to think correctly upon a great number of subjects, on which formerly the grossest errors prevailed. But this very circumstance affords the strongest inducement to promote education, with the utmost speed, through every rank of the community. There are still many evils more or less latently devastating the social fabric, which an improved state of knowledge, and the consequent more exact mode of thinking, would go far to correct. It is an undeniable fact, that within the last two or three hundred years a vast amount of positive delusion, by which the human faculties, moral and intellectual, were for ages kept in thraldom, has almost wholly disappeared from western Europe. Now, if men in general no longer seek to discover the coming incidents of a man's life, or distant events in the history of a people, by studying the course of the stars; or to prefigure the future in the direction of a thunder-clap, or in a shower of stones from the air, or in the flight of a bird, or in some peculiarity of an animal's entrails,—and that less from any profound or widely-diffused knowledge bearing on such subjects, than from a more exact mode of thinking on the course of nature derived from the increasing, though still small proportion of educated minds influencing society—surely there is ground to anticipate that many of the evils still left behind—the fruits of ignorance and unsound thinking—would be eradicated by the general diffusion of education throughout the masses of the community.

Ignorance of Natural Laws.—How slight is the knowledge of the laws of nature, which for the last two or three hundred years has fallen to the lot of each individual, even among the educated orders of society! And yet that mere sprinkling of knowledge in such sciences as Astronomy, Meteorology, Natural History, and Anatomy, has sufficed to banish from this part of the world astrology, divination, sorcery, witchcraft, and magic. What an encouragement does this fact afford to perseverance in that course which, within the narrowest limits, has proved so successful! But there are still delusions remaining to be banished by the extension of sound knowledge. Does the favour extended by the public to clairvoyance, table-turning, and spirit-rapping tell of the advancement of our age beyond the standard of a former one? The age should blush for itself, and take to study. Such study would not only teach what to believe in matters of science, but put it fairly on its guard against blind guides, who every now and then arise, like *ignes fatui*, to mislead the unwary. There are two brilliant examples of these in the present day, who may serve as lessons to the public in the time to come, as having led many astray from the simplicity of truth. They are distinguished men, too—the one an eminent chemist of Germany, the other one of the greatest men Scotland has produced. The public should prize both these men much, but truth more. It is melancholy to think that such men should outlive their faculties; but it is still more melancholy to think that the public should be so little instructed as not to distinguish true from false science.

Statistic Fallacies.—The tendencies of the present age have caused exactness, where men must think without sensible forms before them, to be so generally neglected, that authors who would lose caste and reputation for bad spelling, and still more, for errors in grammar, may violate with impunity the rules of logic, so essential to the teaching of truth. In no department are these rules so often grossly violated as in statistical subjects, where we should certainly expect something like mathematical accuracy. Mr. Farr, the able medical assistant of the Registrar-General, has pointed out a most ludicrous mistake of a logical kind, which cannot be too widely exposed in an age when every man appeals to statistics, and deems himself competent to deal with them. The annual mortality in prison life being required, the statist takes the number of persons who have sojourned in a particular prison during the year, and also the number of deaths that have occurred. He then divides the former by the latter, and points to the result. Such logic is the same as if an innkeeper should boast of the healthiness of his house, as compared to the rest of the town, on the ground that he had, during the year, entertained a thousand guests, of whom only one had died; whereas the mortality for the rest of the town had been at the rate of twelve per thousand. On this kind of logic, however, Mr. Farr tells us that a French minister pronounced prisons to be the healthiest places in the world; and an English inspector gravely affirmed, that in very few situations in life is an adult less likely to die than in a well-conducted prison!

False Induction.—In the ridiculous book of one of the persons to whom we have referred, translated by an eminent professor of chemistry, there is a most unpardonable abuse of the term "induction." One of the purposes of the work is to maintain that some people can see lights assuming the form of human bodies in churchyards, and other places where persons have been buried; and we are told that the evidence on which the German author rests this statement, is an induction of particulars.

Now, what is this so-called induction of particulars? A lady repeatedly says that she sees luminous forms over the graves of the newly-buried. Each repetition of the assertion is gravely set down as one of such a series of particulars, as upon which it is allowed to found an induction. In the first place, there is no evidence of even one of her assertions being founded upon anything but a vagary of the imagination. It is a correct induction, from the particular instances referred to, to say that the lady in question asserts such things; but here the induction ends, and, as regards the reality of the things seen, one assertion is as good as a thousand.

It is melancholy to think that such credulity should exist among men of eminence in special departments of knowledge; but still more melancholy to reflect that the very terms of exact logic should be misunderstood by an eminent professor of an important department of Physical Science.

Education.—The sentiment, so long tolerated in this country, that education might prove hurtful to the masses of society, and unfit them for their ordinary occupations, has long since either died a natural death, or, if not dead, is content to hide its diminished head in some unvisited corner of the land. Nevertheless it is not altogether a settled point what kind of education should be provided for the public. Some simple-minded people limit their notion of education to the humble acquirements of reading and writing; and persons of this stamp are often heard to express their surprise, when they discover that a large portion of our criminal population are masters of these accomplishments. Reading and writing are but the instruments by which education is acquired. And it has been a strange oversight that so much pains have been bestowed in providing our population with the instruments of education, while so few have taken thought to put within their reach the books from which the knowledge yearned after could be reached. To supply in part this want is the great purpose of our present undertaking; and if those who express their surprise that there are among public criminals persons who can read and write, would extend their ideas of education to what includes some acquired knowledge of God, of Man, and of Nature, they would confess that crimes are seldom committed by sound-minded and educated people.

We have asserted that reading and writing are not education, but rather the instruments by which knowledge is to be acquired. It must be admitted, however, that some limitation may be required to this sentiment; since it might be contended that reading and writing stand, in some measure, on the same footing as the several branches of what has been termed "industrial education." But although industrial education, in its special sense, signifies merely that sort of training by which a person may be rendered more apt to learn the kind of occupation which is to be his calling throughout life, and more capable of attaining excellence in it; yet such an education has an additional influence in developing the faculties, both intellectual and moral, far beyond what the mere accomplishments of reading and writing can produce.

Important as industrial education is, for the simple purpose of aiding the development of industry, we must never lose sight of its subsidiary effect in exalting the intellectual and moral character of the individual; nor is it to be doubted that the very best effects may be anticipated from mingling in all schemes of industrial education such studies as belong to Physiology and Psychology, together with those of a directly industrial character, in order to secure a more immediate influence upon the moral character.

There can be no doubt that it is possible so to direct industrial education as to destroy much of the benefit which it is capable of conferring. There is nothing in the study of abstract science and physical knowledge which should withdraw the mind from an acknowledgment of the existence of the SPIRITUAL in the economy of nature. But there is a mode of studying these subjects which makes the properties and laws of matter terminate too much in themselves, without sufficient reference to the power of the INFINITE INTELLIGENCE by which they are maintained and supported.

In all systems of industrial education it should be a first principle that the power which operates in the workings of nature should stand forth acknowledged as the POWER OF GOD; and that man's power of thinking should be confessed as being the foundation of all that his mere senses seem to have discovered of the course of nature.

The term observation is likely to mislead the unwary, who are so often told that all human advancement depends upon observation that they are apt to forget that observation may serve to perpetuate error as readily as to advance truth. They lose sight of the essential maxim that it is instructed observation that at once discards error and establishes truth. It is indeed difficult for an enthusiastic student, amid the profusion of knowledge now set before him, not to believe that all that is necessary to enable an unprejudiced person to understand the order and course of nature, is simply to open his eyes and look around him. It is, then, an instructive lesson for him to discover that, by the same exercise of the senses which seems at once to have laid open the secrets of the universe, all those phantoms, which for so many centuries deluded the human mind, took their origin.

What we here desire to insist upon is, the paramount influence of the state of man's spiritual development at any one time upon his capability of apprehending the economy of nature, with regard to the axiom—that the study of the agency by which knowledge is acquired should never be severed from the study of the things which are made the objects of knowledge.

It is a common idea that the rapid progress of modern science has arisen entirely from a diligent use of the senses, in obedience to the precepts of the Baconian Philosophy. The vast progress of human thought, previous to the possibility of this advantageous use of the senses, is too often altogether overlooked. Thus sense is exalted at the expense of the higher faculties of the mind, and the conclusion arrived at, that the education of the sentient part of our nature is all in all. How erroneous is this idea, will at once appear from the briefest retrospect of the history of man's progress. In man's rudest state there is no want of what passes for knowledge; and his mind is so far from being barren in that stage of progress, or his memory destitute of ideas, that he positively bends under the burden of his thoughts and recollections. Nevertheless, the greater part of this profusion of apparent knowledge with which his mind is filled is entirely false. In a somewhat later stage of progress, this early mass of delusion is represented by the more refined but equally worthless products of sorcery, magic, witchcraft, divination, and astrology.

When we look to the history of man in the first rude ages, we discover an appalling amount of delusion, which we admit has arisen from this tendency to account for what he sees; but, side by side with this heap of rubbish, we find surprising proofs of the exactness with which he has gathered up such laws of nature as are most essential to his every-day well-being. It is when the phenomena are of rarer occurrence, or when they are complex, or when they seldom arise under exactly the same form, that he falls into error. On the contrary, when phenomena come frequently under his notice, if he has erred at first, he commonly obtains the means of rectifying his error. As soon as he discovers distinctly that the succession is not invariable, he ceases to regard the two events as standing in the relation of cause and effect.

It would be easy, then, to show that no just reproach can be thrown against this principle of man's mental constitution. All that he knows of cause and effect he has acquired by a reliance on this part of his mental endowments; and we may justly remark that, in the early stages of his progress, he must have been led to expect, through this principle, the discovery of things placed beyond his reach, owing to the great success with which he had applied the same to the acquisition of knowledge fit for the supply of his every-day wants.

Astrology, divination, sorcery, witchcraft, and magic, are all pursuits seeking to attain a knowledge and power forbidden to man. To these pursuits, doubtless, he was led by this belief, that when two events stand in immediate succession, the first is the cause of the second. By these studies he sought an unattainable knowledge of the future, and an unattainable power over the future; he was dealing with obscure phenomena; he could not readily discover the test afforded by a distinct failure in the succession; and hence these subjects grew to the extent in which history exhibits them. But, during all that while, the knowledge of real causes and real effects was accumulating; and as this real knowledge successively laid open the true order and course of nature, the supposed means of gaining knowledge and power, as respects the future, began to decline.

What we contend for is, the necessity of directing education to the knowledge of the workings of the human mind, as well as to the study of the laws of nature. This we must repeat in season and out of season; and we think we have just shown, by a sufficient detail of facts, that man's knowledge of the course of nature is correct only in so far as he understands the real character of that intelligent agency, his own mind, by which alone, upon earth, the operations of nature are fathomed.

It is a great error to attempt to reduce popular education to a low standard. The power of thinking, and even of thinking deeply, naturally belongs to all sound-minded men. It is the complexity of many subjects of knowledge that have risen up among men which creates the chief difficulty in popular education; and that difficulty is, above all, aggravated by the technicalities of words and symbols, which have been perhaps unnecessarily affected, particularly by those who ridicule the idea of popular education in the profounder parts of knowledge. It is quite true that access to the most profound and exact parts of Physical Science can only be obtained through the abstruse means of mathematical investigation. But there is no room for despair. Although it is impossible, without the application of more time and labour than can be spared by the busy world, to gain a practical acquaintance with the profound means of mathematical investigation, it is within the reach of every one to gain tolerably just ideas of the nature of those powerful instruments of research. All mathematical truth rests, as we have seen, on intuitive principles of the human mind, independently of all experience; and by approaching Mathematics on this side, that is, by considering the fundamental principles of Mathematics in their logical form, not only are the mental faculties enlarged and expanded, but the want of an intimate knowledge of its details is, in no slight degree, supplied to the student of the general economy of nature. To present the various departments of Mathematics in what may be termed their metaphysical form, should be an object with all those concerned in devising the means of placing an enlarged education within the reach of the public. It is not to be wished that men engaged in active pursuits should immerse themselves in the deep cultivation of modern mathematics. Geometry, in the prosecution of which every step is made clear to the mind, cannot but serve to expand the faculties; but the higher departments of Mathematics render the operator too much of a machine, and, unless when the mind is happily constituted, are very apt to spoil the faculties for use in the ordinary concerns of life.

Opinions and Principles.—At the commencement of an undertaking which involves so wide a range of discussion, it is incumbent upon us to make a profession of the rule by which we are to be governed on all those occasions when, in the capacity of instructors, we have to enter upon certain momentous questions that cannot be better indicated than as falling under the heads of OPINIONS and PRINCIPLES.

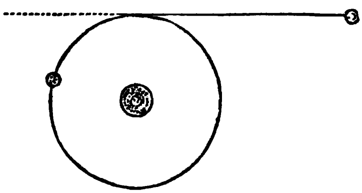
Our paramount rule will be the love of truth. We repudiate the materialism which at present contaminates so much of our popular literature on subjects of science. We shall endeavour to show how groundless—how unphilosophical—are such views of the economy of the universe. We shall take pains, as often as an opportunity occurs, to make it clear to our readers that the faculties of the human mind are qualified to discover something greater than mere law in the economy of nature. We do not fear to promise that the proof of the operation and superintendence of an INFINITE AND PERSONAL INTELLIGENCE will be as completely exhibited as that of the existence of any of the laws of nature which man has discovered.

We shall, on all proper occasions, combat the erroneous notion, now so generally inculcated, that the discovery of a law includes all that the human mind can derive from the contemplation of nature. We know how plausible this notion may be made to appear; and how fascinating it is to think that all the complex operations of nature can be reduced within the limits of a few general laws. But we know also how many are deceived into the belief that such an explanation of the phenomena is satisfactory to the human mind, as including all which, by its constitution, it desires in the search into nature. But do the popular writers who have adopted these views tell their disciples that this specious system of law is designed to supersede all idea of cause—all idea of efficiency—all idea of power—all idea of an overruling Intelligence? It will be easy to show that such is the case, notwithstanding that some may protest that, while they insist upon the universality of law, they never fail to profess their belief in an Omnipotent Creator. We admit that it is so; but we say that it requires but small penetration to see that their logic leaves no room for that GOD in whom their lips alone profess a belief.

Further, we affirm, and challenge contradiction, that the great apostle of such views, from whose works the ideas and reasonings of these writers are chiefly drawn, makes no such limitation in his doctrines; but, on the contrary, he explicitly declares that the age of theology in human science is gone by—meaning, by that expression, that the doctrine of universal law has superseded the idea of a Creator.

We know that some persons cherish the notion that the light of nature cannot carry men to the knowledge of GOD. We will not, however, enter into debate on this point at present; we will only remind those to whom our argument may suggest this sentiment, that what we are contending against is altogether different—namely, the proposition latent in many popular treatises, that human science is positively adverse to the belief in a SUPREME INTELLIGENCE.

It would not surprise us if many of those who have become fascinated with the apparent simplicity of that philosophy which insists upon the universality of law, should persuade themselves that we are misrepresenting their favourite system. They have not discovered that the system involves the denial of an intelligent and infinite First Cause. We have already reminded them that the great modern apostle of the doctrines to which they listen with so much satisfaction expressly says, however seldom the impious words may have been allowed to reach their ears, that philosophy finds no place for God in nature. This philosopher is a most dangerous logician. It is not in his reasoning that flaws are discoverable; it is in his first principles,—and these first principles are exactly those which they have been seduced to think favourably of. Let them not forget that a rigid logic brings out falsehood as certainly as truth, if the principles be false. Among these first principles, all the victims of this system of universal law, we have no doubt, are well familiarized with that which enunciates that, between any two events in nature reputed to stand to each other in the relation of cause and effect, there is no link discoverable except invariable sequence; or that nothing more can be known of their connection, except that the one is uniformly the antecedent of the other—the second the uniform consequent of the first. It follows from this proposition, when stated as above, without any qualification, that the term "cause" is superfluous in reference to the changes which take place in the economy of nature. Authors who have adopted such views, still employ the term cause; but when we examine the use they make of that term, we find it to be exactly synonymous with law. For example, if the question be asked what is the cause of the curvilinear path of the planets, and the answer is, that the attraction of the sun draws them from the straight line, the cause here assigned is manifestly nothing more than a reference to the law of gravitation. The question would have been answered in exactly equivalent terms, if it had been said, by the law of gravitation, two bodies moving otherwise than in the same straight line deflect each other into a curvilinear orbit; and if the one be much inferior to the other in magnitude, the less will circulate around the greater. If, then, there be no case, in the whole of nature, in which, when a change takes place, anything more can be discovered than that an invariable antecedent has been succeeded by an invariable consequent, there is no case in which the term *cause* is applicable in any other sense than as expressive of the law under which the change in question falls, if such a law has been discovered. And if no law including the change has been discovered, then no cause can be assigned beyond the affirmation that such and such a phenomenon has been invariably observed to succeed another phenomenon; that is to say, as a particular instance of an undiscovered law. If, then, man can discover nothing but law in nature, there is no separate sense for the term cause; and if there is no room for the term cause, then there is no known instance of the exercise of power. And if man be incapable of discovering the exercise of power in the universe, then he is incapable of discovering the hand of God; for what is God in nature but Infinite, Intelligent Power? Such is the logical conclusion from the unqualified statement that nothing is discoverable by man, in the investigation of the operations of nature, but a mere sequence of phenomena.



But to this proposition we maintain that an important addition is indispensable. Man cannot, indeed, discover anything but invariable sequence in the phenomena of nature; but he never sees two phenomena thus succeed each other in invariable sequence, without an involuntary acknowledgment that an exercise of power has taken place. This is the addition required to the doctrine of law in physical science; and this feeling of the exercise of power, as often as a change is seen to take place in the universe, is easily proved to be the light of nature, at every moment suggesting to men's minds the presence of Omnipotence.

This point admits of easy illustration. That our earth was once destitute of every living thing, plant, or animal on its surface, admits of the clearest evidence. At a period, how distant from our time is immaterial, the earth became stocked with plants and animals. Here, then, are two states of our planet to be compared together in reference to the signal change implied in the proposition.

We clearly understand that the crust of the earth may at one time have been in a liquid state, owing to the high temperature then prevailing at the surface. Hence all the existing water, and all the volatile chemical compounds, such as the carbonic acid, now so abundantly known in combination with lime, magnesia, and other earths and metallic oxides, would, at that time, form a part of the atmosphere. But by the simple familiar process of cooling, that crust, in the course of ages, would become solidified; the water, along with the less volatile bodies, would descend to the surface, and, dissolving the soluble substances with which it came in contact, would create in them new arrangements, from which the present character of many parts of the crust of the earth would be derived. In such changes nothing is apparent but the activity of laws and properties known to belong at this moment to the Mineral Kingdom.

But although it be now known, from the evidence of chemical analysis, that all the members of the Animal and Vegetable Kingdoms are entirely composed of materials to be met with in the crust of the earth, never has any one property of mineral matter come to light, from which it could be justly conjectured that there is any natural tendency, in the mineral substances composing organic bodies, to pass from the mineral state into any forms of organization, however simple. Here observation is completely at fault. No fact exists to form the very embryo of an induction. The doctrine of equivocal generation held its ground only while uninvestigated; and the alleged results of the experiments of Mr. Crosse, which, if correct, would have been so easily authenticated, are believed by nobody but the credulous and partially instructed. To say that we are entitled to assume that the germs of the organic bodies exist in the minerals of the earth, is to revert to the philosophy of the ancients—to throw aside the precepts of Bacon—to forget that induction consists in first discovering facts, and then principles. If it be said that this is merely an hypothesis brought forward to stimulate inquiry, we simply reply that an hypothesis which has not the shadow of a fact in its favour is no better than an idle dream.

We maintain, then, that the contemplation of the transition of the earth, from a state destitute of living things to one teeming with life, forces upon the human mind, by its very constitution, the conviction that in that vast change, so irreconcileable with the ordinary properties of the mineral matter out of which the organic world has arisen, there has been an exercise of POWER—that is, of a PERSONAL INTELLIGENCE—commensurate with the wonders of the work which has been accomplished.

The philosophy, then, to which we shall uniformly conform throughout our undertaking is easily understood. We set out with the belief that there are other truths within man's reach besides those determined by observation. There are, in the first place, certain necessary truths, which, independently of all observation and experience, man, by the very constitution of his nature, must believe. Of these some are intuitive, and others established by reasoning back to the intuitive truths. The conviction in each individual of his personal identity, and of the reality of all acts of consciousness, are intuitive necessary truths—also such propositions as that, when equals are taken from equals, equals remain; that things which are equal to the same are equal to one another; that things which are doubles or halves of the same, are equal to one another; that twice four are eight; and that when two are taken from four two remain. All Mathematical demonstrations are necessary truths, not intuitive, but resting upon intuitive necessary truths, being established by reasoning back to such truths; for example, that the angle in a semicircle is a right angle, and that two tangents to a circle drawn in opposite directions from the same point are equal.

There are also intuitive truths which are not necessary truths,—that is, intuitive truths, the opposite of which, or a greater or less deviation from which, does not involve a contradiction. The intuitive truths which are not necessary truths, are such convictions as the belief in an external world, and in the free agency of self; the feeling that every event has a cause; and that there is an exercise of power whenever a natural event takes place. There are also truths obtained by reasoning back to those intuitive truths. For example, by reasoning back to the two truths that every event has a cause, and that an exercise of power is felt to have occurred whenever a natural event takes place, we obtain the conclusion, as soon as we can combine with these the observation of the infinite extent of the universe, that there is an INFINITE OMNIPOTENT CAUSE.

Such truths we regard as the first principles on which the superstructure of man's knowledge rests. When this acknowledgment is made, we may embark on the wide ocean of physical investigation, without fear of reaching those impious conclusions to which we have above referred.

When we add, that every proper occasion will be seized to develope the true grounds on which Teleology rests, without at all infringing upon the precepts of Bacon with regard to the possible abuse of final causes in philosophical investigation, we think we have sufficiently indicated the character which this work will sustain as respects OPINIONS AND PRINCIPLES.

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THE

PHYSIOLOGY OF ANIMAL AND VEGETABLE LIFE.

Order in Physiology.—The Physiology of Animal and Vegetable Life, being a subject of great extent, must be methodically treated; and first, it is necessary to determine what principle of arrangement is to be adopted, in order to exhibit, in a connected form, the complete phenomena of these kinds of existence. There are several modes in which such phenomena have been methodized; and it will be convenient briefly to consider some of these, as exhibiting a general view of the whole subject.

The phenomena of animal and vegetable life may be described as Mechanical Phenomena, Chemical Phenomena, Electrical Phenomena, and the peculiar Phenomena of Excitability—the first three orders being common to all departments of nature. A great part of many of the most important actions of the perfect animal body are purely mechanical or purely chemical, or partly chemical or partly mechanical; while such actions are, in their remaining part, the result of a peculiar excitability. In the circulation of the blood, for example, in man, and in the animals resembling man, the blood is propelled onwards by mechanical forces, while these mechanical forces are called into activity in obedience to the laws of excitability. In the function of respiration the air enters the lungs in conformity with the laws of that part of mechanical science termed Pneumatics. The change which the blood undergoes by the contact of this air is a chemical change, or a change closely analogous to a chemical change; while these laws of pneumatics, and the chemical laws, are brought into operation by the agency of an organic excitability. The fluids contained in the leaves of plants in contact with atmospheric air, by the influence of light, undergo a chemical change, or a change exactly analogous to a chemical change; while the leaf presents its upper surface to the light, under the direction of a peculiar excitability.

Excitability, however, can hardly be defined; and in the present state of physiology, it is more a negative than a positive term. All the properties of an organic tissue, whether from the animal or from the vegetable kingdom, which are neither mechanical nor chemical, fall under excitability. Thus, excitability is that which renders animal and vegetable tissues susceptible of certain phenomena, different from the phenomena produced by the same causes on inert matter. For example, with inert matter, the form and textures of a leaf may be exactly imitated; but such an artificial leaf will be destitute of the susceptibility to turn towards the light in sunshine.

Under these several heads all the phenomena of plants and animals might probably be arranged; but the arrangement would be far from convenient.

It belongs to the arrangement of the phenomena of organic life to point out what distinction exists between an organic body and inert matter; and the extreme divisibility of inert matter supplies the readiest ground of distinction. The divisibility of inert matter is either infinite, or, at least, such that no limit can be assigned to it—the minutest portion still retaining all the properties of the original mass. An organic body, on the contrary, is destroyed by division. Again, it seems a universal law, that living bodies alone can give origin to other living beings, either by a partial division of themselves, or by the process of generation; whereas the origin of inorganic substances is always quite independent of any pre-existing substance of a similar kind. Finally, the actions of organic substances, having attained their acme of intensity, gradually decay, and at length, from causes which are inherent in each individual, cease altogether, when the substance becomes at once amenable to the operations of merely chemical and mechanical agents. Such is not the case, however, with inorganic substances, which maintain the same state unalterably, and for any length of time, provided no external agents are brought to operate upon them.

But, from the very earliest times, it has been perceived that a kind of agreement exists between plants and animals; and that, in certain respects, both possess a common nature. In the fifth century before the Christian era, Empedocles taught that seeds are the true eggs of plants; and that plants, like animals, exhibit difference of sex, and a degree of sensibility. Setting out with the idea of this common nature of plants and animals, philosophers naturally next sought to discover some prominent mark of distinction between the two kinds of organic existences. Since the time of Aristotle, in the fourth century before the Christian era, the search after such a distinction has been often renewed; yet, strange to say, almost every distinction hitherto fixed upon, though sufficiently obvious when confined to the higher orders of plants and animals, has been found to fail when applied to discriminate those organic beings lying on the confines of the two kingdoms. The distinction pointed out by Aristotle has been revived in recent times, though hardly with the expected success. This distinction proceeds on the ground that animals receive their nutriment into an internal cavity before it is absorbed into the substance of the body; that plants, on the contrary, absorb their nourishment by the external surface. Animals, in short, have a mouth and stomach; while plants feed by the spongioles of their radicles, and by their leaves.

While this distinction to a very great extent holds good, it cannot be affirmed that it has supplied an adequate test in doubtful cases.

The most recent test suggested for distinguishing whether an organic existence of doubtful aspect belongs to the vegetable or to the animal kingdom, is of a chemical character. Starch is a constituent of vegetable tissues; and by the blue colour which iodine imparts to starch, even when present in the most minute proportion, it can be detected, wherever it exists, with the greatest facility. This substance, starch, then, being supposed not to exist in the animal kingdom, promised to solve the long-studied problem, or, at least, to be the only test of distinction which, until very lately, could hold its ground; but the recent researches of some German physiologists have demonstrated the existence of particles of an amylaceous nature in some of the lower animals; and even in the brain and spinal cord of man a substance, termed cellulose, hitherto presumed to be proper to vegetables, has been discovered.

It is not to be concluded, however, because so great a difficulty occurs in discriminating from each other those plants and animals which stand on the confines of the two kingdoms, that the laws governing the vegetable economy are identical with those governing the animal economy.

On this important point, we will cite the following passage from the recent work of one of the most distinguished of living physiologists (*Valentin's Physiology*, by Brinton):—

"The constant physical and chemical changes which accompany life depend upon various exchanges, which are produced by the work of the different parts of the body—the extrusion of what is useless; the assimilation of what is received; and the restoration of the organs, by which all these operations are effected. The whole of the *vegetable* or *general organic functions* on which nutrition and generation depend, are repeated in every living body. It has often been supposed that all their particulars correspond in the two organic kingdoms; that there is a digestion, a respiration, a perspiration, and an excretion, in plants as well as animals. But a more accurate examination teaches that this is not the case. Vegetables possess no tissues which allow of the same kind of nutritive absorption, of distribution of juices, or of secretion, that we meet with in, at least, the higher animals. They have no large cavities in which considerable quantities of food can be collected and dissolved by special fluid secretions. They possess no point midway in the movement of their juices, and no mechanism, other than that of a casual and secondary apparatus for the inhaustion or the expulsion of the respiratory gases. They are devoid of the changeable epithelial coverings, which play an important part in many of the animal excretory organs. In one word, the general organic functions are introduced into the two living kingdoms of nature, and probably into their subordinate divisions, by two different ways. This difference leads at once to the conclusion, that the structure of the animal is not a simple repetition of that of the plant, with the addition of a series of new apparatus. The nature of the tissues, the mode of their actions and change—the form, division, and destiny of the organs—all these rather teach us that animals of any development are constructed upon an altogether different plan."

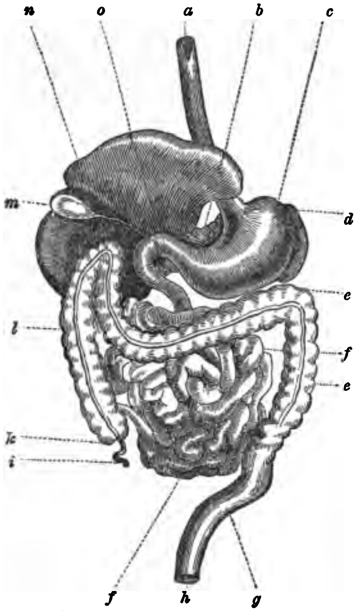
Whatever in the above quotation may appear obscure to those to whom physiological ideas are new, will be cleared up, we trust, by what we are about to say on the prominent distinctions between those organic existences which are unequivocally animals, and those which are unequivocally plants, with reference to a basis for the arrangement of the phenomena of vegetable and animal life.

In physiology, the term function is of continual occurrence. What, then, does function signify? Function is the use of a part or organ. The function of the eye is sight; that of the ear, hearing; that of the lungs, the purification of the blood by ventilation; that of the stomach, digestion; that of the liver, to secrete bile. In plants—that of the spongioles of the radicles, to absorb from the soil; that of the leaves, to decompose the carbonic acid of the atmosphere, so as to appropriate the carbon for the uses of the plant; that of the anther, to impregnate the ovule, by means of its secretion, the pollen; that of the ovary, to mature the ovule into a seed.

As the functions in all the higher animals and the higher plants are numerous, there is room for method in the arrangement of them. Various methods have been suggested; and, in accordance with some one or other of these arrangements, it has been common to methodize the various topics belonging to physiology.

The kinds of function common to plants and animals, are properly termed vegetative functions—the same which are called vegetable or general organic functions in the quotation from Valentin. The kinds of function, not so obviously possessed by plants, so as to seem peculiar to animals, are named the animal functions.

The vegetative functions are the functions of maintenance; the animal functions are the relative functions, or the functions of relation. The vegetative functions end in the organism of the individual, or, at most, in the organism of the species; the functions of relation establish relations between the animal and the world without.

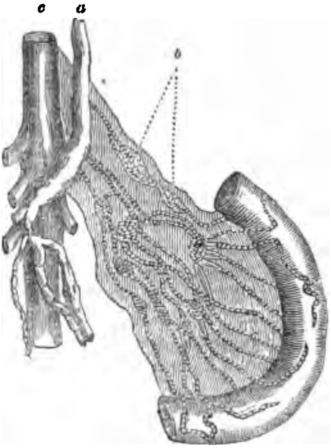


DIGESTIVE APPARATUS OF MAN.

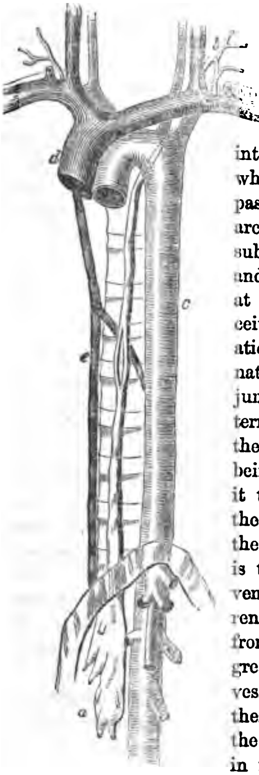
a, œsophagus; *b*, pancreas; *c*, stomach; *d*, spleen; *e*, colon; *f*, small intestines; *g*, rectum; *h*, anus; *i*, appendix of cæcum; *k*, cæcum; *l*, large intestines; *m*, gall-bladder and ducts; *n*, liver; *o*, pylorus and stomach.

If we follow the food, in one of the higher animals, from the mouth to its incorporation with the previously existing tissues of the body, the waste of which it is its office to supply, we shall discover what are the more immediate vegetative functions—the same which, by other names, are known as the functions of maintenance; the functions of nutrition; the assimilative functions, or functions of assimilation; and the functions of organic life.

The food—let it be a piece of meat, or bread—is reduced to a pulp by the movements of the teeth, and the admixture of the saliva, secreted by the salivary glands; it is then swallowed by a somewhat complex muscular action. It is moved about in the stomach by the contraction of its muscular fibres; and, being mixed with the gastric juice, a peculiar fluid secreted by the lining membrane of the stomach, it passes into chyme: this chyme is then, in successive portions, transmitted, by muscular contraction, into the highest part of the intestinal tube, termed the duodenum, which is a kind of second stomach, where the partially assimilated food is first mixed with the bile, and then with the secretion derived from the sweetbread, or pancreas. The mass is now ready to afford chyle, the immediate nourishment of the blood, to the absorbent vessels, termed lacteals, the extremities of which abut on the lining membrane of the higher parts of the intestinal tube, while the residue is sent downwards by what is termed the peristaltic action of the tube, for evacuation. The chyle, taken up on a very wonderful plan by the lacteal tubes, is transmitted through the singular small organs termed the mesenteric glands, whence, after important changes, it is again collected by what are named the efferent lacteal tubes; these by degrees unite together into a trunk, which joins the lymphatic vessels coming from the pelvis and the lower parts of the body, to form the thoracic duct *a*, commencing in the abdomen, dividing opposite the middle of the dorsal vertebræ into two branches, which soon reunite, passing behind the arch of the aorta and subclavian artery, and making its turn at *b*, where it receives several lymphatic trunks, terminates at the point of junction of the internal jugular and subclavian veins on the left side of the neck, and into which it pours its contents. The chyle, being thus mixed with the venous blood, is carried with it to the right side of the heart; and, by the motion of the heart, is thoroughly mingled with that blood; from the right side of the heart the blood, reinforced by the chyle, is transmitted to the lungs, where, by exposure to the air, the venous blood is converted into arterial; the arterial blood, so rendered fit for the nutrition of the body, being sent forth from the left side of the heart, is conveyed by the aorta, the great arterial trunk, and its branches, to the capillary blood-vessels, which pervade all the sensible parts of the body. From these capillary blood-vessels, the several component textures of the living frame attract the new matter, of which they stand in need; while that which is already reduced to the state of debris, re-enters the blood of the capillary system, and returns with the blood, now become venous, to the right side of the heart. The blood, having become impure by the admixture of the debris of the tissues, and from other causes, is purified, partly by the lungs, by which a superfluity of carbon is thrown off, while, by the slow combustion which it sustains, animal heat is developed; and partly by the kidney, of which last organ the particular office plainly is to keep the blood free from the various chemical products generated during the successive decompositions which the textures and their first debris undergo.



CHYLE VESSELS.
a, thoracic duct receiving lacteal tubes from *b*, the intestine; *c*, aorta.



THE COURSE AND TERMINATION OF THE THORACIC DUCT—*after Wilson.*
c, the aorta; *d*, the superior cava; *e*, the greater vena azygos, in which, in some mammals, the duct terminates.

Such is a rapid sketch of the functions named vegetative in the higher animals, while it indicates the order in which each comes into operation. This sketch also indicates why the epithets nutritive and assimilative, often applied to this order of functions, are not inappropriate; assimilative signifying the making a thing to be of like kind, and bearing reference to the object of these functions being to convert the aliment into a like substance with the body. Thence it appears, also, that the epithet vegetative is rightly applied to this order of functions; because all the obvious functions of plants have the same object, namely, the conversion of their aliments, such as water, carbonic acid, and ammonia, into the vegetable texture. Even in popular language a person is said to vegetate, when he does nothing to withdraw himself from the category of those "fruges consumere nati,"—born to eat and drink.

How inactive soever a person may be, while he vegetates he lives. It is by the exercise of the vegetative functions that life is preserved. As an order of functions they are—some more directly, some less directly—necessary to life. Hence the vegetative functions are sometimes termed the vital functions. But the term vital, as applied to functions, having been used for ages in a restricted sense, should be wholly laid aside. By the older physiologists the term vital was confined to those functions, the uninterrupted exercise of which is indispensable to the life of the higher animals; namely, the circulation of the blood, the respiration, and that part of nervous action which is necessary for the continuance of the circulation of the blood and the respiration. It is undeniable that these three functions are pre-eminently vital. If any one of these is arrested, even for a very short period of time, the others likewise cease, and immediate death is the consequence. Thus, there are three modes of death readily produced by accident, or disease, corresponding to the three so-called vital functions: death by the heart, death by the lungs, and death by the brain.

While, however, the remaining vegetative functions—Digestion, Secretion, and Excretion, according to the terms longest in use among physiologists—may be interrupted for a time without the loss of life—being not less necessary to life in the main than the three functions just referred to—they are fully entitled to the epithet vital, unless convenience altogether forbade the use of that term.

The vegetative functions, then, are common to plants and animals, in so far as both plants and animals possess functions concerned in nutrition; but the particular functions concerned in that process in plants do not exactly correspond to the special nutritive actions in animals.

There is another order of functions common to plants and animals—namely, the functions of reproduction. These are commonly regarded as distinct from the vegetative functions; although, by taking a somewhat larger view of the term "vegetative," they may be properly included under that name. Thus, if the vegetative functions—namely, the functions of nutrition or assimilation—be held to terminate in the individual, whether plant or animal, then there must be adopted a separate order of functions, under the name of reproductive. But if the larger, and, perhaps, more correct view, be made choice of, that each species is one whole in physiology, having a determinate duration, from the present individuals down to the last survivors, then the reproductive functions, as necessary to the life or continuance of the species, will fall under the same definition as the functions of maintenance in general. According to this view, then, the vegetative functions in plants and animals are the functions during the activity of which the life of a species continues.

The non-vegetative functions are not essential to life; they are present only when the actions of the organic being do not terminate in itself, or in its species. In man such non-vegetative functions have their highest development. They are the functions by which relations are established between the individual and the world without. Such relations fall under the two heads of relations of knowledge and relations of power,—in general terms, the functions of locomotion and of sense. The same functions in man may be described as the functions of consciousness, including sensation, thought, and volition.

To this statement it need only be added that the vegetative functions correspond to the functions of organic life, while the relative functions are identical with those of animal life.

TABLE OF THE FUNCTIONS IN MAN.

I.—VEGETATIVE FUNCTIONS.

Circulation of the blood	Vital, of Old Authors.
Respiration	
Digestion, Absorption	Natural, of Old Authors.
Secretion, Excretion	
Reproduction	Formerly separate.

II.—FUNCTIONS OF RELATION.

Locomotion, Thought,
Sensation, Voice.

Such, then, is the ordinary general arrangement of the functions of animals, founded on presumed differences in their essential condition—the first class, requiring for their display only a general property common to all living matter—the latter, some specific properties in addition. There is also another foundation for such an arrangement, in certain general ends, to which more or fewer of the several functions—independently of the individual end to which each is subservient—conjointly conduce. These general ends are three—the ultimate object of every function being either to preserve the individual in a state of life and health, to perpetuate its species, or to maintain its relation with the external world. Of these, the first extend no further than the individual, and have no ulterior end; the second is exercised for the sake, not of the individual, but of the race; and the third furnishes us with the only means which we possess of maintaining an intercourse with each other, with Nature, and with Nature's God. Their consideration is well calculated continually to inculcate upon the mind the main purposes of our existence as living and rational creatures; and to lead us to observe, while investigating the phenomena of each function, the admirable adaptation of the means to the object, not only individual, but general, for which this function was appointed, and to which, in common with others, it conduces, as subservient, directly or indirectly, to the great end of our being.

We pass over the systematic arrangements usually followed in studying the animal and vegetable existences, and which are commonly discussed in physiological works. Such subjects, in our Circle of the Sciences, will fall under the general divisions of Zoology and Botany, where they will be more fully explained than could be possible in a general treatise. We therefore at once proceed to the consideration of

THE ULTIMATE AND PROXIMATE ELEMENTS OF ORGANIC BODIES.

The chemical constitution of Organic Bodies is most readily understood by a reference to what have been named their Ultimate Elements, and their Proximate Elements. The ultimate elements are all those substances found in organic matter which rank as simple bodies in modern chemistry; that is, bodies which have hitherto resisted all further analysis. In the whole of nature, chemists admit the existence of no more than sixty-three or sixty-four such simple bodies. Out of these sixty-three or sixty-four elementary substances, seventeen exist in organic nature.

The PROXIMATE ELEMENTS are formed by the union of several of these ultimate elements. Most commonly three or four ultimate elements unite in large proportion, while a few others are present in very minute proportion. The proximate elements, in which there are three principal ultimate constituents, are termed ternary compounds; those containing four are called quaternary compounds. The ultimate elements, which enter in large proportion into the ternary and quaternary proximate elements of organic nature, are the simple constituents of air and water—namely, oxygen, nitrogen, carbon, and hydrogen. As examples of the proximate elements formed out of these, united in different proportions, we may enumerate albumen, well known under the form of white of egg, and caseine, the essential constituent of cheese—what, in short, makes up nearly the whole of well-pressed cheese made from skimmed milk; also the starch extracted from the flour of wheat and sugar; and lignine, which constitutes ninety-five per cent. of wood.

As the proximate elements are made up of ultimate elements, so the solid textures and fluids of organic bodies are composed by the union of the proximate elements. By the union of textures, organs are formed; by the union of organs, the body itself is framed. Here, then, we obtain a mixed analysis of the organic frame, in part chemical, and in part mechanical.

The modern idea of the organs being made up of textures, so that each might be conceived as being reducible to its ultimate mechanical elements, was a happy improvement on the ruder notion of ancient times, which represented the animal body as consisting of flesh, blood, bone, skin, hair, nail, gristle, sinew, nerve, brain, &c. What, then, is a texture? This question is more easily answered by examples than by a definition. The muscular flesh—that is, the lean of beef or mutton—is the muscular texture or tissue; the substance of the brain and nerves is the nervous texture or tissue; the connecting medium of the several organs of the body is the cellular tissue, called also the filamentous, or areolar tissue; and these three are the best distinguished textures or tissues of the animal body. In the vegetable kingdom, the cellular tissue is almost the only texture.

This kind of mechanical analysis does not admit of a rigid exactness; because it is only in idea, for the most part, that the decomposition can be carried out to a complete mechanical simplicity. Hence, in a practical point of view, we do not define a texture as a simple solid, as if the next act of decompounding would bring us to the proximate chemical elements contained in it, but content ourselves with saying, in the plural number, that the textures are the simpler solids which enter into the structure of complex parts and organs.

This general view being premised, we must now look a little more narrowly—1st, into the ultimate elements; 2ndly, into the proximate elements; and, 3rdly, into the component textures of organic bodies.

The ultimate elements are divisible into two orders: those which are at once in larger proportion and more constantly present; and those which, while they usually exist in small proportion, follow a more variable rule as to their presence or absence in the several textures. In the first order, as before pointed to, stand Oxygen, Hydrogen, Carbon, and Nitrogen. In the second order we find Chlorine, Iodine, Bromine, Fluorine, Sulphur, Phosphorus, Potassium, Sodium, Calcium, Magnesium, Silicium, Iron, and Manganese.

In a third order, two or three simple bodies might be placed, which are met with accidentally along with the proper elements of organic matter.

ULTIMATE ELEMENTS OF THE FIRST ORDER.

Oxygen.—This chemical element, when in the isolated state at common temperatures, exists in the form of a gas, with the properties of common atmospheric air, which is indeed oxygen gas diluted, and thereby rendered less energetic in its effects. Oxygen gas is essential to the life of plants and animals; but unless diluted, it destroys both by its excessive stimulus. It supports the combustion of combustible bodies, such as phosphorus, much more vividly than atmospheric air. In combination with other bodies, oxygen exists, diffused extensively throughout the three kingdoms of nature. Besides nearly making a fourth part, by weight, of the atmosphere, it constitutes eight-ninths of the whole weight of the waters of the globe, and not far from one-half of the weight of the common crust of the earth. In the animal kingdom, it forms something less than the fourth part of the weight of dried muscular flesh, and one-half of the weight of lignine, which, as we have seen, is nearly identical with wood. There are, indeed, but few natural bodies at the earth's surface which do not contain oxygen. These are easily enumerated,—the few bodies which exist in a simple form; carbon as in the state of diamond; sulphur in some of its states; such metals as are found in the virgin state; the combinations of metallic bodies with chlorine, iodine, and sulphur,—for example, the beds of rock-salt, and the sulphurets of iron, copper, and zinc.

The process of combustion, in which oxygen plays so important a part, is not altogether foreign to the subject of Physiology. Combustion is a chemical action, in which the union of one body with another is attended with development of heat, and, under ordinary circumstances, with an evolution of light. When a bit of phosphorus is introduced into a jar of pure oxygen gas at an elevated temperature, the phosphorus unites so rapidly with the oxygen, that vivid combustion is exhibited. What, then, is the source of the heat? To resort to the common explanation, the compound formed has a much less capacity for heat than the oxygen and phosphorus taken together; hence the excess becomes developed or sensible, having been before latent. Or, the explanation may as usefully be drawn from the rule, that when a body passes from a rarer to a denser state of aggregation, as from the gaseous to the liquid or the solid state, heat is uniformly evolved. In the case under consideration, the phosphorus, by uniting with the gaseous oxygen, rapidly condenses it into a solid, in which state the compound exists; and so, in obedience to that rule, much heat is evolved. In most cases of combustion, the temperature of the combustible body must be raised considerably above the common temperature of the atmosphere, by some means independently of the combustion; but as soon as the union between the combustible and the supporter of combustion commences, as between the wick of a lamp charged with oil and the atmosphere, then new heat is developed.

The product of the union of the two bodies in combustion is not always solid, as in the case of phosphorus and pure oxygen gas, more frequently the product is gaseous; thus, when charcoal, a form of carbon, burns, whether in oxygen gas or in atmospheric air, the product is carbonic acid gas—the same gas which is continually discharged from the lungs of animals with the expired air. Nevertheless, heat is evolved in this case,—the oxygen becoming considerably denser by the addition of the carbon. Of late, in the chemistry of the animal kingdom, the term combustion has been extended to include those processes of oxidation which take place slowly within the bodies of animals, accompanied by an evolution of heat; the distinctive name eremacausis, or slow combustion, being employed in this sense. By this eremacausis, not only do the simpler forms of carbon within the animal body, become changed by combination with oxygen into carbonic acid, but the salts which contain a vegetable acid, as the acetates, the tartrates, and citrates, pass into carbonates of the same base, just as the tartar of wine (the impure bitartrate of potassa) is changed by a destructive heat into carbonate of potassa, so long known, as derived from this source, by the name of salt of tartar.

Nitrogen.—Nitrogen, like oxygen, exists, at the ordinary temperature of the earth's surface, in the gaseous state, and possesses the common physical properties of atmospheric air. Unlike oxygen, however, it can support neither combustion nor life. It forms nearly four-fifths of the atmosphere by weight, it exists but sparingly in the mineral kingdom, and is not contained, like oxygen, in the common rocks of the crust of the earth. Its chief source in mineral nature, besides the atmosphere, is in two orders of salts, the nitrates and the salts having ammonia for their base. It exists also in the compound mineral inflammables, such as coal, justly regarded as being of vegetable origin. It exists in both the organised kingdoms of nature, yet is much more extensively diffused in the animal than in the vegetable kingdom. Under the head of the nutrition of plants, nitrogen must come in for a large share of attention.

Hydrogen.—Hydrogen is a gaseous body, and the lightest of known ponderable substances. The great source of hydrogen is the waters of the globe, of which it forms one-ninth part by weight. It does not exist in the rocks of the crust of the earth, unless in so far as they contain water. Combined with nitrogen, it is present in ammonia. It makes up about one-sixteenth part of the whole weight in the tissue of wood, and nearly the same in starch and sugar; and of dried muscular flesh it forms about one-thirteenth by weight. In such proportions, then, does the hydrogen of water contribute to the substance of animal and vegetable tissues.

Carbon.—At ordinary temperatures carbon is a solid body; and its most familiar form is the charcoal of wood. Uncombined, it exists very sparingly in the mineral kingdom; but combined with oxygen, in the form of carbonic acid gas, it exists abundantly, as in combination with earthy and metallic bases,—such as the carbonate of lime, the carbonate of magnesia, the carbonate of zinc. The carbonate of lime, as chalk, marble, limestone, marl, is one of the most abundant substances in mineral nature; and of this substance carbon forms one-seventh part by weight. In the atmosphere carbonic acid is uniformly present, but in variable proportion. It exists also in waters. The respiration of animals and the combustion by common fires are continually adding to the carbonic acid of the atmosphere; while the process of vegetation is as constantly decomposing it, appropriating to itself the carbon, and setting free the oxygen. In dried muscular flesh the proportion of carbon by weight is not far from one-half; and in the tissue of wood the weight of carbon is nearly three-sevenths.

ULTIMATE ELEMENTS OF THE SECOND ORDER.

Chlorine.—Chlorine does not exist free in organic nature, but only in combination with metallic bases, or with hydrogen. The chloride of sodium, or common salt, is a constituent of the animal fluids, and in certain classes of animals must be regarded as essential to life, because it is the source of muriatic or hydrochloric acid, the presence of which is one of the conditions of their digestion.

Iodine.—Iodine exists in sea-water, in some mineral waters, and in a few minerals. Its chief source, however, is the oceanic algæ or sea-weeds; it exists also in sponges; and has been detected in the oyster and other marine molluscs.

Bromine.—Bromine exists also in sea-water, and in some mineral waters. It has been found in marine plants, and in the ashes of at least one animal, the janthina violacea, one of the testaceous molluscs.

Fluorine.—Fluorine exists, combined with lime, in the bones and teeth of animals. It has been found also in the vegetable kingdom to a sufficient extent to account for its existence in the animal kingdom. In the mineral kingdom it exists in great abundance.

Sulphur.—Sulphur exists as widely diffused in the mineral kingdom as in volcanic products, also combined with metallic bodies, and in mineral waters; and to these sources in the mineral kingdom should be added the sulphates,—such as the sulphates of lime, as selenite, alabaster, and plaster of Paris; the sulphate of magnesia, or Epsom salts; and the sulphate of baryta, or heavy spar. In the vegetable kingdom sulphur does not exist in much profusion; the sulphates are among the salts met with in the analysis of vegetable tissues; and sulphur is particularly found in some orders of plants, as the cruciferous family and the lichens. In the cruciferous plants—such as the coleworts—the presence of sulphur is indicated by the smell of sulphureted hydrogen, given off during their decomposition.

Phosphorus.—Phosphorus hardly exists free in any part of nature. The salts which its acid combinations with oxygen form, are widely spread through the three kingdoms of nature, and appear to have important offices assigned to them in the economy of organic life. Phosphorus exists diffused through all fertile soils. The source from which these important constituents of vegetable and animal substances originally reach the soil, is now proved to be the mineral kingdom. The phosphate of lime exists in the mineral kingdom under two forms—namely, apatite and phosphorite—which, though in some districts they constitute even mountain masses, yet are not widely spread over the earth's surface. But recent chemical analysis has satisfactorily shown that minute portions of phosphates are everywhere spread throughout the earth's surface; so that nothing is easier than to understand, that by the disintegration of these rocks—a process at all times in activity—minute portions of phosphates are continually added to the adjacent soil. Even in sea-water phosphates have been detected. As to the existence of phosphorus in the vegetable kingdom, the ashes of red wheat contain, according to Liebig, 94·44 per cent. of phosphates; the ashes of white wheat, 91·47 per cent.; the ashes of pease, 85·46 per cent.; the ashes of beans, 97·05 per cent. of the same salts; whence it follows that the ashes of these several substances have phosphorus present in them to the extent of 15 to 20 per cent. And as phosphates are invariable constituents of the seeds, not only of all kinds of grasses and leguminous plants, but also of the seeds of plants in general which are fit for food, it is not too much to say, that phosphorus, in minute proportions, is spread throughout the vegetable kingdom.

In the animal kingdom phosphates make a prominent figure among its saline constituents. It has even been believed of late that uncombined phosphorus exists in the animal body, as in albumen and fibrine.

If the phosphates in the human body amount to about one-fifth part of its weight, as indicated by some calculations, then every human body must contain several pounds of phosphorus. The phosphates, and particularly the phosphate of lime, are the chief hard materials of the bones in vertebrated animals, the carbonate of lime being in very inferior proportion. In the true shells, as in those of the crustaceous molluscs, or testaceous animals, there appear to be no phosphates, the hard substance being almost entirely carbonate of lime; but in the true crustaceous animals, as in the shells of the lobster, crab, and crayfish, there is both phosphate of lime and carbonate of lime, the latter predominating. In egg-shells there is a portion of phosphate of lime, while the predominating constituent is the carbonate of lime. The bone, as it is termed, of the cuttle-fish, contains no phosphate of lime. In the zoophytes the composition of the indurated part varies in different animals. Madrepore consists entirely of carbonate of lime, without phosphate; and the red coral yields a little phosphate of lime. In the higher animals phosphates are found generally throughout the fluids and soft parts, as well as in the skeleton.

Silicon, or Silicium.—Silica, or silicic acid, is found in small proportion throughout the organised kingdoms of nature. In the animal kingdom it is met with, in trifling quantity, chiefly in the bones and in the urine. In the vegetable kingdom it performs the important office of imparting strength to the stem, as in grasses, so as to enable them to support the weight of the grain. In the stem of the equisetacea, or horse-tails, the silica is seen to be disposed in a crystalline arrangement. In the bamboos of the East Indies there occurs a deposit of pure silica in considerable masses, to which the name "Tabashen" is given, and to which various mystical properties are ascribed.

Potassium.—The ashes of trees and of herbaceous plants growing elsewhere than on the sea-shore, contain the carbonate of potassa; and such is the sufficient proof of the existence of potassium generally throughout the vegetable kingdom. The proportion of potassium varies considerably in different plants; and those which contain a large proportion refuse to grow in soils not rich in salts of potassa. The carbonate of potassa was formerly called the vegetable alkali, as if it belonged peculiarly to the vegetable kingdom. But it is now well ascertained, that all the potassa of the vegetable kingdom had its original source in the mineral kingdom, whence, by the disintegration of the rocks containing it in small proportion, new supplies are continually passing into soils.

In the animal kingdom potassium is not found so extensively diffused. Salts of potassa exist in some of the fluids of the human body, as in the blood, the milk, the urine. The same salts are abundant in the urine of herbivorous animals; that is, the excess of potassa received with vegetable food is thrown off by the urine.

Sodium.—In the ashes of sea-weeds, and of plants growing on the sea-shore within reach of sea-water, the carbonate of soda exists. Kelp and barilla are the names applied respectively to the soda obtained from these two sources. Soda was formerly termed the mineral alkali, and perhaps it is more easily obtained from the mineral kingdom than potassa, owing to its salts existing in a more isolated form in that kingdom; for example, the chloride of sodium in the shape of rock-salt and sea-water, the nitrate of soda, and natron, found in certain districts of the globe. Soda, like potassa, exists also diffused through mountain rocks in minute proportion; for example, the difference between felspar and albite, or natron felspar, is, that in the latter the potassa of the felspar is replaced by soda.

Soda is more particularly the alkali of the animal kingdom. Besides the chloride of sodium, widely diffused, as already mentioned, in the animal kingdom, the sulphate of soda, the phosphate of soda, and various combinations of soda with the organic acids, are met with, particularly in the animal fluids.

Calcium.—Lime, or the oxide of calcium, exists widely spread in organised nature. In the vegetable kingdom the salts of lime everywhere exist in minute proportion, while in the animal kingdom these salts accumulate so as to obtain a particular prominence, as has been already indicated under the head of phosphorus.

Magnesium.—Magnesia, or the oxide of magnesium, exists much more sparingly than lime in organic nature. Phosphate of magnesia is a salt of continual recurrence in the chemical analysis of the parts of vegetables. Thus, in the ashes of wheat, rye, beans, and pease, the phosphate of magnesia exists to a considerable extent. It also occurs in the human blood, and in the bones.

Iron.—Iron appears to possess important offices in organic nature. Its oxide exists, combined with phosphoric acid, in such seeds as wheat, rye, and pease; and the oxide is discoverable in the ashes of various kinds of wood,—for example, in the ashes of fir-wood the oxide has been found to the extent of 22·3 per cent. In the animal kingdom iron is a universal constituent of the blood.

Manganese.—Manganese is found in the analysis of various woods, and also in the human hair.

THE PROXIMATE ELEMENTS OF ORGANIC NATURE.

The proximate elements of organic nature are divisible into the azotised and non-azotised proximate elements; that is, into those which contain nitrogen, and those destitute of nitrogen.

Albumen, fibrine, and caseine are proximate elements, common to both kingdoms. According to a view which has excited much attention, these three proximate elements are merely slightly modified forms of the one proximate element, proteine. Mülder, the author of this view, conceived that the compound to which he gave the name of proteine was the basis of these several substances, and that the difference in their properties depended on the circumstance that the proteine in each was united with a different proportion of sulphur, or, in some cases, of sulphur and phosphorus and salts. A degree of doubt still envelopes this view; but certain it is, that the three proximate elements just enumerated, differing as they do very materially in properties, agree very closely in ultimate composition. All the three, whether obtained from the vegetable or from the animal kingdom, consist of oxygen, hydrogen, carbon, and nitrogen, with a proportion of sulphur and phosphates; the proportion of nitrogen being about fifteen or sixteen per cent.

Albumen.—This proximate element is most conveniently represented by the white of eggs. It is soluble in water, and exists dissolved in the serum, or watery part, of the blood, and in vegetable juices. It is coagulated by heat; that is to say, after having been exposed to the heat indicated by the 160th degree of Fahrenheit's thermometer, it ceases to be soluble in water, and several chemical agents produce the same effect as heat upon it. Albumen exists in the serum of the blood; in the secretions poured into what are termed the shut cavities of the animal body, such as the thorax and abdomen; in the humours of the eye; in the bile; in the muscular tissue; and, more or less modified, in many of the animal solids. It is met with, also, in many vegetable juices, and in seeds, such as nuts, almonds, &c.

Fibrine.—Like albumen, fibrine is known under two forms—the coagulated and the non-coagulated. The latter is found in fresh-drawn blood and in fresh-drawn vegetable juices; but, on standing, each coagulates. In the coagulated state it exists naturally in muscular flesh, in the gluten of wheat flour, and in the seeds of the grasses.

Caseine.—In milk caseine is found. It does not coagulate spontaneously, like fibrine, nor by heat, like albumen, but by the action of acids it coagulates. Cheese made from skimmed milk, and well pressed, is nearly pure caseine. The name legumine was formerly applied to a substance quite identical with caseine, found in the seeds of leguminous plants. The ashes of caseine are rich in phosphate of lime and in potass. Coagulated caseine is a compound of caseine with the acid employed in the coagulation.

When milk, by long standing, seems to coagulate spontaneously, the effect is produced by the previous generation of lactic acid, a portion of which has combined with the caseine. In the oily seeds, such as almonds, nuts, &c., caseine is present, together with albumen.

Gelatine.—Isinglass represents the chemical body termed gelatine, which consists of carbon, hydrogen, nitrogen, oxygen, and sulphur. To speak strictly, it does not exist in the animal tissues, but is formed out of certain of these by the action of boiling water. Gelatine is soluble in hot water, and by cooling forms a jelly. It is precipitated by tannic acid, and upon this property depends the formation of leather. The gelatinous tissues, as they are termed, are the bones, the tendons and ligaments, the cellular tissue, or filamentous tissue, and the membranes in general. Glue and size are formed from such tissues by long boiling. Gelatine is found to be more closely allied to albumen, fibrine, and caseine, than was at first supposed. It is believed, however, that it cannot be transformed within the animal body into albumen, fibrine, or caseine; and that is the reason why animals fed exclusively on gelatine die with symptoms of starvation.

Chondrine.—Between gelatine and chondrine, which forms the tissue of cartilage, there is a close resemblance; with this difference, however, that chondrine is not precipitated by tannic acid.

Horny Matter.—Of horny matter there are two varieties, the membranous and the compact. The membranous constitutes the epidermis and the epithelium, or lining membrane of the vessels, the intestines, the pulmonary cells, &c. The compact forms hair, horn, nails, &c. Feathers are allied to horny matter.

Hematosine.—The colour of the blood is due to a peculiar albuminous principle, termed hematosine.

Globuline.—In the blood-globules, besides hematosine, there is another albuminous principle, on which the name globuline has been bestowed.

Kreatine.—There has been obtained of late, from the juice of flesh, a remarkable substance, to which the name kreatine has been given. It is a crystalline compound, consisting of oxygen, hydrogen, carbon, and nitrogen. It has neither acid nor basic properties. It is very soluble in hot water, and cold water retains a minute portion of it in solution. By the action of strong acids it is resolved into a new body, named kreatinine. Kreatine has been found, in minute quantity, in the muscular flesh of the common domestic quadrupeds, and also in that of birds and fishes.

Urea.—The chief peculiar constituent of the urine is urea, which consists of oxygen, hydrogen, carbon, and nitrogen, the last being the predominant element. Although, then, the constituents of urea are the same as those of albumen, fibrine, and caseine, the proportions are very different. In those albuminous bodies the proportion of nitrogen is only about 15 per cent., while in urea it is 47 per cent. In those so-called forms of proteine the carbon amounts to 52 or 53 per cent.; while in urea it is no more than 20 per cent. In the former, the hydrogen is very much the same per cent. as in the latter; but the oxygen in urea is 27 per cent., while in the forms of proteine it is about 22 per cent.

Uric Acid.—In uric acid the proportion of nitrogen is also great, while that of carbon is also considerable. The nitrogen is present to the extent of 32 per cent., while the carbon amounts to 37 per cent. Uric acid is secreted, not only by animals and birds, but also by serpents and many insects. Guano consists chiefly of uric acid combined with ammonia.

Hippuric Acid.—In the urine of graminivorous animals another acid has been discovered, to which the name hippuric has been given. In this acid there is no more than 8 per cent. of nitrogen.

THE NON-AZOTISED PROXIMATE ELEMENTS OF ORGANIC BODIES.

Oil, or Fat.—For sake of convenience, we still speak of the oily constituents of organic bodies as proximate elements, though, strictly speaking, the oily acids, of which these oils consist, are the true proximate elements. The term fixed oil, or fat, denotes a compound of oxide of glyceryle with certain organic acids, chiefly compounds of that oxide, with stearic, margaric, and oleic acids,—two of these, and often all three, being present. In animals, fat occurs chiefly in the cellular membrane, or in a tissue connected with it. Among plants, oils occur in the seeds, capsules, or pulp surrounding the seeds, and very seldom in the root.

Starch.—Fecula, or starch, as already stated, has only lately been recorded as existing in the animal kingdom. In vegetable nature it is everywhere met with. It occurs abundantly in the seeds of the cerealia; in the tubers of tuberiferous roots, as in the potato; in the stems of palms; and in lichens. Starch, by its ready convertibility into soluble forms—such as dextrine and sugar—is well fitted to act important parts in the economy of vegetable nature. It appears to be stored up in the seeds, roots, and pith of plants, to supply materials for some of the most essential vegetable products.

Gum.—The mucilaginous compound, gum, is widely spread throughout the vegetable kingdom. It is soluble in water, and insoluble in spirit. Its precise uses in the vegetable economy have hardly yet been made known.

Lignine.—The basis of wood, and of the stems and leaves of herbaceous plants, is termed lignine, or woody fibre. It is a fibrous matter, insoluble in all ordinary solvents, and is left after vegetables have been successively exposed to the effects of ether, alcohol, water, diluted acids, and diluted alakalies. Lignine forms about 95 per cent. of baked wood, and is the chief constituent of linen, paper, and cotton. Lignine, together with starch and gum, constitutes the principal mass of the vegetable kingdom.

Such are the chief proximate elements of the organised kingdoms of nature; as to the rest, it would be tedious to enter upon any allusion to them at present, while such of them as deserve particular attention, will meet with the necessary mention in the further course of this treatise.

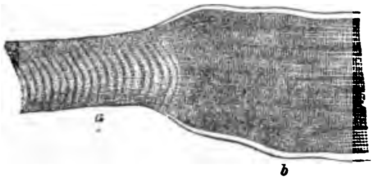
THE CHIEF COMPONENT TEXTURES OF ORGANIC BODIES.

It will be sufficient to exhibit a few distinct examples of the character and properties of the component textures of organic bodies, without attempting, at this stage of our undertaking, to exhaust the whole of the details which might come under this section.

In the animal kingdom, as before hinted at, there are three well-distinguished textures, namely, the muscular, the nervous, and the filamentous. In the vegetable kingdom there is only one distinct texture, namely, the cellular.

The muscular tissue—to confine our attention to a single fibre—has the property of shortening and elongating itself by a molecular movement of its minute constituent parts, so as to impart a mechanical impulse to the adjacent solids, or fluids. In the meantime the cilia, as they are termed, or the minute bodies observed in motion on membranous surfaces, may be ranked with the muscular texture, though it be still uncertain to what extent the molecular action in each is different. The nervous texture has the property of being so influenced from without, as to execute and regulate the movements of muscular fibres. The muscular and the nervous textures admit of little modification, retaining nearly the same structural character under all kinds of circumstances. The third texture, the filamentous, being merely the connecting medium of the several component parts, may be regarded as suffering various modifications, or, at least, as representing various other tissues, particularly membrane, bone, and cartilage.

The Muscular Texture.—Two kinds of muscular fibre are known in the animal kingdom, and these, in the higher animals, are well distinguished from each other. One of these occurs in the voluntary muscles, and is named, from conspicuous cross markings, the striped muscular fibre; the other, found in the alimentary canal, the womb, and the bladder, being destitute of such cross markings, is termed the unstriped. In the heart and the gullet both kinds are met with. The elementary striped muscular fibres are arranged in sets parallel to each other; the unstriped muscular fibres, on the contrary, cross each other at various angles, and interlace, being arranged like membranous organs enclosing a cavity, which, by their constriction, is contracted.



CONTRACTION OF STRIPED MUSCLE—*Philos. Trans.* 1840.
Fragment of elementary fibre of an eel partially contracted in water—magnified 300 diameters. *a*, uncontracted part; *b*, the contracted part.

The striped fibres are usually as long, or nearly as long, as the muscle in which they exist. They vary in diameter from one-sixtieth to one-fifteen-hundredth of an inch; they are of the greatest breadth in crustaceous animals, fishes, and reptiles, and of least breadth in birds. Their average width in the human body is one-fourteen-hundredth of an inch. They are not cylindrical, but more or less flattened. This primitive fibre consists of a great number of primitive particles, or sarcous elements, enclosed in a tubular organ, termed sarcolemma.

The ordinary diameter of the unstriped fibre is from one-two-thousandth to one-three-thousandth part of an inch. It is doubtful if they possess a sarcolemma. The absence of cross stripes seems to arise from a less uniform arrangement of their interior particles, or sarcous elements.

In the lower animals, the distinctive characters of these two kinds of primitive muscular fibre begin to be confounded, especially when the fibres become much reduced in size. The transverse stripes become irregular, not parallel, and interrupted; and sometimes a fibre shows the transverse stripes near its centre; in short, as the fibres become extremely minute, these anatomical characters are lost; and this may be the reason why in infusory animalcules, the wonderful movements of which they are capable cannot, even with the best microscopes, be referred to the presence of muscular structure.

Each primitive muscular fibre is properly regarded as a distinct organ complete in itself; and there are instances in the animal kingdom of a striped muscle consisting of a single fibre, and this fibre containing only a single file of sarcous elements.

Whenever a primitive muscular fibre preserves a rectilineal direction from end to end, the movement it undergoes is simply rectilinear; but the compound organs, termed muscles, in the human body, and in the larger animals, consist of many thousands of these primitive muscular fibres: still, however, the result must be described as a mechanical traction, compounded of the rectilineal motion, in a number of minute fibres, or parts of fibres, as to length, that original rectilineal motion being the effect of molecular movement of the sarcous elements within the primitive fibres.

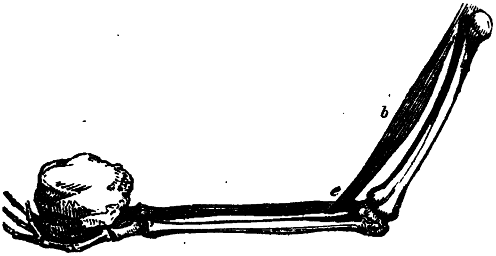
These primitive muscular fibres are plainly extravascular; that is, the minute blood-vessels which nourish them and replace their substance, continually reduced to inert chemical products by the exercise of living action, do not enter the fibre, but merely convey the blood to its exterior surface, whence the nutrient matter is attracted into its interior.

Of the nervous filaments supplying the primitive muscular fibre, a like remark may be made as respects all those animals in which nervous filaments can be traced to the component fibres of a muscle. The primitive tubules of a nerve "pass among the fibres of a muscle, and touch the sarcolemma as they pass; but, as far as present researches have informed us, they are entirely precluded by this structure from all contact with the contractible material, and from all immediate intercourse with it."—*Physiological Anatomy*, by Todd and Bowman, vol. i. p. 168.

Contractility.—The property of a muscular fibre to shorten itself on the application of a stimulus, and, by a quick alternation, again to return to its former length, is contractility. When, then, the contractility of a muscular fibre is spoken of, the term is to be understood in this special sense, or as indicating the quick alternation of shortening and lengthening. In the works of Haller, the greatest of physiologists, this special property of muscular fibre is termed irritability. But as irritability may be sometimes employed in a larger sense, contractility appears to be the more appropriate term. At the same time, it cannot be denied that irritability includes contractility; that is to say, that contractility of muscular fibre is a species of irritability, and the same thing may be said of excitability. The contractility of a muscular fibre, in the sense here indicated, is a species, or form, of its excitability.

The stimulants which call the contractility of a muscular fibre into activity, are either mechanical, as irritation with a sharp instrument; chemical, like some acid chemical fluid; electrical, like a shock of galvanism; or psychical, like the human volition.

When a muscular fibre, the opposite extremities of which are attached, for example, to adjacent points of two bones, is made to shorten itself forcibly by the application of a stimulus, the more moveable point is drawn nearer to the more fixed point; and this is the great law on which locomotion by muscular fibres depends. Thus the fore-arm is bent upon the arm by a muscle, *b*, which arises from the top of the latter, and which is inserted at *e*, at a short distance from the elbow-joint. A very slight contraction will raise the hand, but a considerable increase of power is required to overcome a resisting force.



BONES OF ARM, HOLDING WEIGHT.

Tonicity.—There is another form of muscular contraction, which may or may not be the result of the same property, modified by a difference of circumstances. In past times, however, it has been regarded as a different property, and is known by the name of tonicity. The character of this so-called property of the muscular fibre is better taught by examples than by description. If a muscle in the living body be cut right through, each portion, after a few quivers, begins slowly to shorten itself in a permanent manner, so that an empty space is left between the two cut extremities. There being no tendency in these two shortened portions to return to their former length during an indefinite term, this effect has usually been ascribed to a property different from contractility, under the name of tonicity. Whenever, by any change of the relative natural position of the parts of the skeleton, as by fracture or dislocation, the points to which the opposite ends of a muscle are attached are brought nearer to each other, the muscle becomes permanently shortened by the same so-called tonicity. Again, if the muscles which extend or straighten a joint become paralysed, without a corresponding loss of power in the antagonistic muscles which bend that joint, then the flexor muscles, as they are termed, become shortened by their tonicity, and the joint remains permanently bent. This explains the permanent bent state of the elbow-joints in the paralysis of the upper extremities attendant on the painter's colic, to which all artisans are exposed whose occupations bring them into daily contact with preparations of lead.

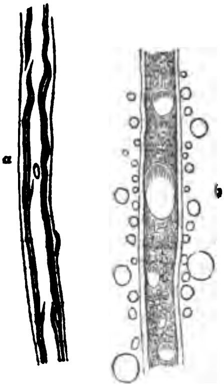
Some forms of permanent lock-jaw seem to be of the same character; the muscles closing the jaw, which correspond to flexors, remaining in full vigour, while their antagonists have lost their power.

Muscular Texture.—The muscular flesh constitutes a large proportion of the soft parts of the animal frame. In the higher animals nearly the whole of the muscles are attached to the skeleton, or are skeleton-muscles. In common quadrupeds there is a peculiar subcutaneous muscle—the panniculus carnosus—by which these animals are enabled to move the integuments, so as to shake off from their skin insects and other annoyances. In the human body there is a muscular expansion occupying the neck, corresponding to the subcutaneous muscles in quadrupeds, which anatomists term platysma myoides. The platysma myoides and panniculus carnosus, in higher animals, are conceived to represent an entire system of muscles, which, in its full development, belongs to a different part of the animal kingdom. For example, in the crab and lobster, the muscles which move the limbs are inserted into the shell, which is plainly the integument of these animals, though in them it takes the place of a skeleton. Thus the muscles of locomotion in the crab and lobster are a highly developed system of subcutaneous muscles, corresponding to the platysma and panniculus, or the hypodermal system in mammals, and which, as opposed to the skeleton system of muscles, belongs in general, under its developed state, to all animals, with the exception of the vertebrata. As organs of motion, the ciliary processes, or cilia, might be spoken of with the muscular tissue; but will be referred to elsewhere.

Nervous Texture.—The nervous matter exhibits two forms, the vesicular and the fibrous. The vesicular nervous matter is gray, or cineritious, in colour, and granular in texture; it contains nucleated nerve-vesicles. The fibrous nervous matter is white and tubular; in some parts, however, it is gray, and its fibres are solid. When both these kinds of nervous matter are united into a variable-shaped body, that body is termed a nervous centre; and the threads of fibrous matter which pass to and from it, are termed nerves. The office of the latter is called "internuncial;" that is, they establish a communication between the several parts of the body and the nervous centre, and between the nervous centre and the several parts of the body.

Of all the solids, the nervous matter comes nearest to the fluid condition. It contains from three-fourths to seven-eighths of its weight of water. In general terms, its chemical analysis may be thus given: albumen, seven parts; fatty matter, five parts; water, eighty parts; while the remainder consists of inorganic matter, the chief of which is phosphorus, if not free, in the state of phosphoric acid.

The fibrous nervous matter is most extensively diffused throughout the animal body. It enters largely into the nervous centres, and is the chief constituent of the nerves, which extend in every direction. Besides the tubular fibre, or nerve-tube, there is also what is termed the gelatinous fibre; the latter is much less abundant, being found chiefly in the great sympathetic nerve. In the tubular fibre, there is externally the tubular membrane, analogous to the sarcolemma of the striped muscular fibre. A white substance, called the white substance of Schwann, forms an interior tube, and within that the material is transparent. The nerves-tubes lie parallel to each other, and never branch. In the cut, *a* represents a nerve tube in water. The delicate line on its exterior indicates the tubular membrane. The dark, double-edged inner one, is the white substance of Schwann, slightly wrinkled. *b* is the same in ether. Several oil-globules have coalesced in the interior, and others have accumulated round the exterior of the tube. The white substance has in part disappeared.



NERVE TUBES OF THE EEL, in water and ether—*after Todd and Bowman*. Magnified 300 diameters.

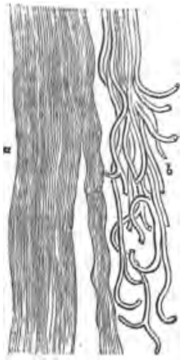
The vesicular matter exists in the nervous centres; but is never found in nerves. It essentially consists of vesicles or cells, containing nuclei and nucleoli. The wall of each vesicle is formed of an extremely delicate membrane, containing a soft but tenacious finely granular mass. The prevailing form is globular; but that figure is liable to be changed by packing. There is also a kind of nerve-vesicle, termed caudate, from exhibiting one or two tail-like processes.

A nerve is a leash of nerve-fibres, surrounded and connected by areolar tissue. The areolar tissue surrounding the nerve-fibres is called the neurilemma: from the internal surface of which, processes are sent inwards, to form partitions between the smaller leashes and the individual fibres. The blood-vessels are distributed upon the investing neurilemma and its partition-like processes—and thus the individual nerve-fibre is, like the ultimate fibres of the muscles, extravascular. The nerve-fibres within the sheath lie in simple juxtaposition, the several fibres being parallel to each other. These fibres, which in the cerebro-spinal nerves are chiefly of the tubular kind, while varying considerably, do not exceed the one-fifteen-hundredth of an inch in man and the mammalia.

Areolar Tissue, Membranes, &c.—The areolar tissue of recent authorities has a very perplexing number of names. Among the newer names applied to this tissue, is that of filamentous tissue. It is the tela cellulosa, the cellular tissue of the older authorities, called also cellular substance; but, in its ultimate structure, it appears to be of a fibrous character, and hence the term cellular is inappropriate. The areolar tissue is most extensively diffused over the animal body, connecting the other component parts of the frame in such a manner as to allow of a greater or less freedom of motion between them. Owing to this manifest use of the areolar tissue, the additional name "connexive tissue" has been proposed for it. It is placed in the interstices of other textures in greater or less abundance, and in a more or less lax state, according to the exigencies of the case. It everywhere surrounds the blood-vessels, and is hardly absent in parts supplied with blood. In the more solid parts of bone, in teeth, and cartilage, it does not exist; nor scarcely in the substance of the brain, except around the larger blood-vessels. In the muscles it connects the elementary fibres together, yet does not penetrate the sarcolemma, or touch the contractile elements within. It is remarkable, that abundant as it is in the muscles at large, it is in very sparing proportion within the substance of the heart. It exists largely immediately beneath the skin; and hence it is this lax layer of areolar texture which is the seat of the dropsy termed anasarca, and of the occasional accumulation of air termed emphysema.

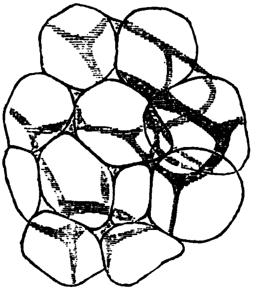
The areolar texture, moreover, surrounds all the organs, particularly those, like the pharynx, gullet, lumbar colon, bladder, &c., which have no free surface. It dips also into the interior of organs, and connects their proper anatomical elements together. It appears, however, that the importance of the areolar tissue in the parenchymatous organs, as they are named—the lungs, the liver, &c.—has been overrated. It always attends the distribution of the blood-vessels in such organs; "but wherever, either from the intricacy of the interlacement of the capillaries with the other essential elements of the particular organ, or the greater strength of these elements themselves, the firm contexture of the whole is provided for, while little or no motion is required between its parts, this intersticial filamentary tissue will be found to be confined to the larger blood-vessels, and to the surface of the natural subdivisions of the organ."—*Todd and Bowman*, vol. i. pp. 77, 78.

Under the microscope, the areolar tissue presents an inextricable interlacement of tortuous and wavy threads, intersecting one another in every direction. Of these threads there are two kinds, the white fibrous element, and the yellow fibrous element. The threads of the former are inelastic, of unequal thickness, forming bands with the marks of longitudinal creasing, the largest of the bands being often one-three-hundredth part of an inch in width. The threads of the latter are long, single, elastic, branched filaments, disposed to curl when not put upon the stretch, and for the most part about the one-eight-thousandth part of an inch in thickness. They interlace with those of the white fibrous element, but there appears to be no continuity of substance between them. By the crossing in endless succession of these microscopic filaments, and of their fasciculi, there results a most intricate web, the interstices of which are most irregular in size and shape, while all necessarily communicate with one another. These interstices are not cavities possessed of definite limits, since they are, in fact, formed out of a mass of tangled threads. It appears at once, then, that the term cell is inappropriate to these interstices. In certain parts, however, of this texture, secondary cavities, not inappropriately termed cells, occur, particularly in the subcutaneous cellular tissue in which fat accumulates. These secondary cavities, or cells, often visible to the naked eye, have a somewhat determinate shape and size.



a, white, and *b*, yellow fibrous tissue, *after Todd and Bowman.* Magnified 320 diameters.

The fatty or adipose tissue has the like office of filling up interstices with the areolar tissue; and hence, being found almost constantly associated with that tissue, it has been too commonly regarded by anatomists as merely one of its modifications. The adipose and areolar tissues, however, appear to be altogether distinct and independent. It has, indeed, long been remarked that there are many situations in which areolar tissue uniformly exists in which fat never appears, while there are some situations—for example, in the cancelli of bones—exhibiting a copious deposit of fat, without any vestige of areolar tissue. And as the two tissues seem to be quite distinct, even in those situations where both exist in proximity, the old term adipose cellular tissue should be discarded.



FAT VESICLES—*after Todd and Bowman*, assuming the polyhedral form from pressure against one another.

Fat is not to be confounded with adipose tissue. The tissue is the thin membrane, thrown into closed vesicles, or cells; the fat is what these vesicles, or cells, contain. The tissue, or membrane, is about the one-twenty-thousandth part of an inch in thickness, and is quite transparent; it is of the simplest structure, and incapable of further mechanical analysis. Each vesicle is a distinct organ in itself, varying from one-three-hundredth to one-eight-hundredth part of an inch in diameter.

The fat itself is a form of oil, resolvable into stearine, oleine, and margarine.

Fat is extensively diffused through the animal kingdom. It exists not only in perfect insects, but also in the larvæ. It is found in molluscs. In all the tribes of vertebrated animals it is met with. In many fishes it is found only in the liver,—as the cod, the whiting, the haddock, and the rays. In reptiles it exists chiefly in the abdomen. In the frog, toad, &c. it is found in long bands on each side of the spine. In birds it exists chiefly between the peritoneum and the abdominal muscles; also, however, in the bones of the extremities, particularly of the swimming tribes. In mammals generally it abounds, yet with some exceptions; for example, the hare, in which sometimes hardly a particle of fat is discoverable.

In the healthy human fœtus fat accumulates in considerable quantity after the middle of the period of gestation. The quantity of fat in a moderately fat man has been estimated at about one-twentieth of his weight.

The white fibrous tissue and the yellow fibrous tissue are not confined to the areolar texture. The white fibrous, or inelastic fibrous tissue constitutes the ligaments of the joints and skeleton, the tendons of the muscles, and the membranes termed fibrous membranes. The yellow fibrous tissue, or the elastic fibrous tissue, forms some structures of great importance in which elasticity is requisite, as in the ligamenta subflava of the spine, and various parts of the mechanism of the larynx and windpipe. A peculiar modification of this texture constitutes the middle or proper coat of the arteries.

Simple membrane, together with epithelium, or epidermis, constitutes the tegumentary surface of the body, internal and external, or the mucous surfaces and the integuments; while an epithelium, spread over expanded cellular tissue, constitutes the serous membranes, or the linings of the shut cavities.

In the higher animals the mucous and serous membranes are well distinguished from each other. The former line the open cavities of the body: one extends in man, for example, from the frontal sinus into the cavities of the nose, ear, and mouth, and descends by the windpipe to line the countless number of minute air-cells; on the other hand, it passes through the gullet to the stomach, and so through the small and great intestines to the extremity of the rectum. The second great mucous membrane may be described as commencing in the pelvis of the kidney; it descends through the ureters to the bladder, and from the urethra, in both sexes, is transmitted into the organs of generation. The first of these great mucous membranes is termed the gastro-pulmonic membrane; the second, the genito-urinary mucous membrane. Owing to the extreme minuteness of the air-cells, which the pulmonic mucous membrane lines, the area of that membrane far exceeds the whole extent of the surface of the body.

The serous membranes line the great shut cavities of the body. The peritoneum, or serous membrane of the abdomen, is the largest membrane of this class. The membrane itself is a shut sac, like a double nightcap. The sac within contains nothing but secretion, the secreting surface being everywhere in contact with itself, that is, with another portion of the same inner surface of the sac; the inner or secreting surface being everywhere free, that is, unattached, while the outer surface is called the surface of attachment, because it is at every point united by coalescence with adjacent organs or parts.

Besides the peritoneum, or serous membrane of the abdomen, the serous membranes of the human body are,—the pleura, forming two separate shut sacs within the chest; the pericardium, or serous membrane of the heart, often termed fibro-serous, as having a fibrous layer in connexion with it; the serous membrane of the brain, the arachnoid membrane; the serous membrane of the testicle, the tunica vaginalis; to which may be added, the synovical membranes, or membranes of the joints, and the bursal membranes, in which the great tendons play.

THE BLOOD IN RED-BLOODED ANIMALS.

By a happy phrase the blood has been described as "circulating flesh," or *chair coulant.* It ranks with the fluids; but the term fluid in Physiology differs widely from its signification in Physics. The blood is water, containing a considerable portion of solid organic matter. Human blood is about five per cent. denser than water; that is, human blood is water charged with about five per cent. of organic solid matter. The heaviest part of the solid matter of the blood consists of what are termed red particles, cr the red corpuscles, and these it is possible to separate by filtration from the remaining part of the blood. To succeed in this experiment, however, the blood of an animal must be chosen, in which the blood-corpuscles are considerably larger than in the human blood. In the frog the blood-corpuscles are four times the size of those in the blood of mammals. If, then, the blood of a frog be placed on a filter of common white filtering paper, a transparent fluid passes through the filter, and the red particles remain on its upper surface. By this experiment the blood is actually divided into the two parts, to which, respectively, physiologists attach a particular value. In the language of modern authorities, the portion which remains on the upper surface of the filter is the vesicular part; that which passes through is the "liquor sanguinis," or blood plasma. The portion which passes through the filter, after a few minutes begins to coagulate. The coagulum, or clot, gradually contracts with an exudation of watery fluid, by which it remains surrounded. The part which coagulates is fibrine; the liquid part, or what is usually called the serum, being subjected to a temperature considerably short of that of boiling water (160° Fahrenheit), forms another coagulum, which is found to be albumen, or nearly identical with white of egg. The watery fluid which remains over is called serosity. This serosity contains all the soluble salts of the blood, and nothing else but a little animal matter.

Such, then, is a brief outline of the constituents of the blood; and even in the so-called white-blooded animals, the composition of the blood is very much the same, since the absence of colour depends less on the total deprivation of red particles, than on the small proportion of that constituent being present.

We are now prepared better to understand what happens when blood is drawn from a vein in the human body. After a few minutes, blood so drawn assumes on the surface the appearance of a jelly, from which, after a time, drops of watery fluid here and there begin to ooze out; these drops become more and more numerous, and finally unite, so as to cover the jelly-like surface with a layer of watery fluid. After a short time, the clot, of which the jelly-like surface is the upper part, is so surrounded with the exuded watery fluid, as to be entirely separated, in most cases, from the sides of the vessel. The clot, however, does not always preserve the same degree of consistence. It is sometimes large, soft, and flabby; at other times small and firm, almost leathery. It consists, as might be anticipated, from what has been already stated, of the red particles and fibrine, or that substance which spontaneously coagulates when the blood of a frog has been subjected to filtration. The coagulation, then, of the clot depends on the coagulation of the fibrine which it contains, and not at all on its remaining chief constituents, the colouring corpuscles. When the clot is examined from top to bottom by a perpendicular section, it shows, in most cases, the red colouring matter diffused throughout, yet plainly in larger proportion at the lowest part, to which, owing to their greater weight, they gravitate before the coagulum has acquired sufficient consistence to intercept their progress. The colouring matter near the upper surface is usually of a more intense red colour than that below, owing, doubtless, to the action of the atmospheric air, by which the dark colour of venous blood acquires the vermilion hue of arterial blood. In every case the clot retains within it a portion of serum, or of the watery part of the blood. When the fibrine coagulates more weakly than usual, a larger proportion of this watery part is retained, giving to the clot an unusually soft and flabby consistence. Hence, without taking into account the degree of consistence of the clot, the relative proportion of the clot to the serum cannot be estimated. Of two cases in which the proportions are alike, the clot will be large in that in which the coagulation is weaker, and small in that in which the coagulation is stronger; the apparent quantity of the serum being greater in the latter case, owing to the large proportion of it retained in the clot. When the clot is large, and at the same time very firm, the fibrine is both abundant and highly coagulable.

The surface of the clot is generally quite flat; in other cases it is remarkably concave, or cupped, as it is termed. And when it is cupped, it is most commonly covered with a more or less thin layer of a yellowish opaque jelly, well known to physicians by the various names of size, buffy coat, and inflammatory crust. This yellow or buff-coloured layer on the surface of the clot, as its last-mentioned name indicates, is regarded by physicians as marking an inflammatory state of the body in the person from whom the blood was drawn. This layer is composed of the fibrine of the blood, separated from the red particles on the surface of the blood just before the clot forms. The unusual tendency to separation between the fibrine and the colouring particles, in cases where the buff is to appear, may be discovered while the whole blood is still fluid, by placing the cup between the eye and the light, when thin films, not unlike oil upon water, of a dark colour, will be seen floating on the surface of the blood. These films are plainly layers of fibrine already separated, through which, owing to their tenuity, in most cases, the dark colour of the venous blood shines. When the buff is to be very thick, these layers of fibrine on the surface of the still fluid blood, being opaque, exhibit their natural yellow colour. At the same time that there is this greater tendency to a separation between the red particles and the particles of fibrine, it has also been observed that the red particles have an unusually great disposition to unite together in the form of rolls, like piles of coins.

The following table exhibits, from recent authorities, the mean relative proportions of the several chief constituents of human blood in the two sexes:—

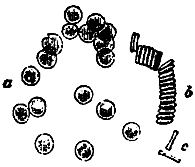
	Male.	Female.
Water	779	791
Red particles	141	127
Albumen	69·4	70·5
Fibrine	2·2	2·2
Extractive matters and free salts	6·8	7.4
Fatty matters	1·6	1·62

What particularly strikes us on glancing at the table, is the small proportion of fibrine and the large proportion of albumen, notwithstanding that fibrine appears to be the nutrient constituent of which the most important solids of the body stand chiefly in need. Nay, the proportion of fibrine stated in the table is even an exaggeration, since what are termed the colourless blood-corpuscles cannot be sufficiently detached from the fibrine. The large proportion of red corpuscles also creates surprise, since these corpuscles are not directly concerned, as far as is known, in the nutrition of the solids. By far the most abundant solid in mammals, like man, is the muscular flesh. This muscular flesh is almost entirely made up of fibrine, identical, or nearly identical, with that which exists, however sparingly, in the blood. Further, when the animal body is much exercised, the muscular tissue is that which must require the greatest amount of repair; since it plainly appears that every living act is attended with a chemical decomposition and consequent waste in the organ concerned. It is impossible, then, to suppose that the small proportion of fibrine existing in the blood should be the source of repair to the muscular system. The proportion of fibrine in the blood is no more than one-fifth per cent.; so that, if the whole blood of the body be estimated at twenty-five pounds, the quantity of fibrine will be the one-twentieth of a pound, or something more than five drachms. It will hardly be maintained that the small proportion of fibrine in the blood arises from its unceasing exhaustion by the nutrition of the muscular tissue, for, were this the case, fibrine would increase enormously in the blood, after a few days' complete repose from muscular action.

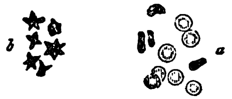
Is it probable, then, that the albumen of the blood supplies the waste of the muscular tissue by passing into fibrine, when it is attracted from the liquor sanguinis into that tissue? In this supposition there is no difficulty. We have seen that albumen is very nearly identical with fibrine in ultimate composition; and it is certain that the egg, out of which the chick is developed,—that is to say, fibrinous flesh as well as blood, membrane, and bone,—consists of nothing but albumen, a little oil, and some saline matter. Of albumen there is about seven per cent. in the human blood, or in the mass of the circulating blood there is something less than two pounds of albumen. Even this quantity will not suffice to supply the waste of the muscular tissue long, not to speak of the other demands upon it, without being continually renewed by the addition of the products of digestion.

As the proportion of fibrine in the blood is not found to diminish under deficiency of food, it has been conjectured that it is the result rather of the decomposition of the blood itself, or of some of the tissues, than that it is designed to sustain any share in nutrition. But this view is not yet sufficiently matured to permit of being dwelt upon in this place.

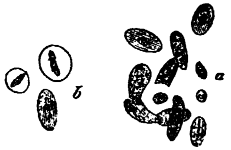
The whole subject of the red corpuscles of the blood still presents great difficulties. Many observations have been made upon these bodies throughout the animal kingdom; but the exact use which they serve in the living frame is still a problem. These corpuscles constitute about 14 per cent. of the whole mass of human blood, or there is about twice as much by weight of the red corpuscles in the blood as there is of albumen, and seventy times as much as there is of fibrine.



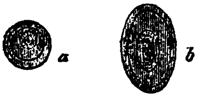
RED CORPUSCLES FROM HUMAN BLOOD, magnified 400 diameters—*after Todd and Bowman.*
a, viewed on the surface; *c*, in profile; *b*, aggregation of corpuscles in a roll.



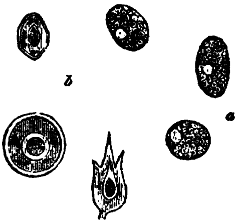
RED CORPUSCLES OF THE OX, magnified 400 diameter — *after Todd and Bowman.*
a, in their natural state; *b*, altered by a menstruum of higher density.



RED CORPUSCLES OF THE PIGEON, magnified 400 diameters — *after Todd and Bowman.*
a, unaltered, with two or three colourless particles; *b*, treated with acetic acid, which more clearly developes the cell-wall and nucleus.



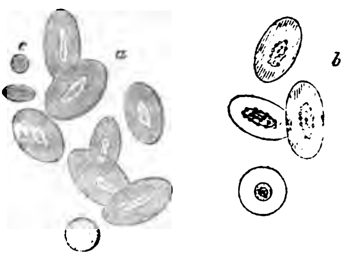
RED CORPUSCLE IN FISHES—*after Wharton Jones.*
a, lamprey; *b*, skate.



RED CORPUSCLES OF CRAB—*after Wharton Jones.*
a, three granule cells; *b*, three nucleated cells.

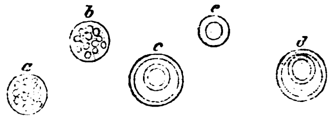
When a drop of human blood is placed under the microscope, nothing but an opaque mass is seen, owing to the crowded state of the fluid with red corpuscles; but when the drop is diluted with a weak solution of salt or of sugar, each corpuscle is seen detached from the rest. The fluid used to dilute the drop of blood must be, as nearly as possible, of the same specific gravity as the serum of the blood; if plain water is employed, the red corpuscles swell and burst. Each corpuscle is round and flat, like a piece of money; or, to speak more correctly, each corpuscle has the form of a double concave lens, the margin being thick and rounded, and the centre considerably thinner: their size in the human body varies from the three thousandth to the four thousandth part of an inch in diameter. In mammals generally the blood-corpuscles are similar in figure to those in man; but there is a considerable variety of size in different tribes of these animals. They are small in ruminants, in the Napu musk-deer being no more than the twelve-thousandth part of an inch in diameter. In the camel tribe, instead of being round, they are oval, as they are in birds, reptiles, and fishes. In reptiles the blood-corpuscles attain a large size.

In the frog, the red corpuscles consist of a delicate membrane forming a cell, within which is a granular nucleus. The nucleus is globular, and much smaller than the cell; and the space between the inner surface of the cell and the outer surface of the nucleus is filled by fluid, holding the colouring matter in solution. The nucleus cannot be detected in the red corpuscles of the human body, but analogy suggests that its structure must be of the same general character as in the animals, in which these corpuscles are of larger size.



BLOOD CORPUSCLES OF THE FROG, magnified 400 diameters—*after Todd and Bowman.*
a, in serum fully developed; *b*, treated with acetic acid; *c*, colourless corpuscle.

A question has arisen, whether what have been termed the colourless corpuscles of the blood be a distinct set of bodies, or merely the red corpuscles in a less developed state. The colourless corpuscles are spherical bodies, destitute of colour; they are cells composed of a very delicate membrane, and the cells are nucleated. The addition of weak acetic acid renders the cell-membrane, the nucleus, and the nucleolus more distinct, by dissolving some granules contained within the cells. The colourless corpuscles slightly exceed the size of the red corpuscles in mammals, but not in the other vertebrata. They are thought to be essentially the same as the nucleated particles found in lymph, and in the chyle. They are fewer in number than the coloured corpuscles, being, it is said, in the proportion of one to fifty. In inflammatory states of the blood they become more abundant; and, after great loss of blood, the proportion of these colourless corpuscles is greatly increased. Without entering upon the difficult question, what is the relation between these colourless corpuscles and the red corpuscles, it will be sufficient to say, in the meantime, that the weight of authority is in favour of these two kinds of corpuscles being identical in species, that is, merely different stages of one organism.



PHASES OF THE HUMAN BLOOD-CORPUSCLES—*after Wharton Jones.*
a and *b*, granule cells in the coarsely and finely granulated state; *c* and *d*, nucleated cells; *c*, without colour, and *d*, with colour; *e*, free cellæform nucleus, a perfect red corpuscle.

According to this view, then, to quote a passage from Todd and Bowman's *Physiology*:—"In the earliest periods of fœtal life, the blood-corpuscles, as is shown by the researches of Vogt, Kölliker, and Cramer, originate in the same way as the elements of the tissues, from nucleated cells, which are the same, in point of constitution, as the colourless corpuscles; with this exception, that they contain, between the nucleus and cell, a considerable number of granules, which are largest at the earliest periods of embryonic life. At later periods similar nucleated cells are generated in the liver, as first pointed out by Weber, and from these sources supplied to the blood. In this fluid they undergo a transformation into the completely formed blood-corpuscles, by the removal of the granules, the increased development of the nucleus, and the generation of colouring matter, excepting in the mammiferous corpuscles, whose ultimate change seems to consist in the complete absorption of the nucleus, according to Kölliker, or the removal of the wall of the cell, according to Wharton Jones.

"Now, as there can be no doubt that, in the adult, the lymphatic and chyliferous systems afford a source for the constant development of particles identical with the colourless corpuscles, and as such corpuscles are always found in considerable proportion in the blood (being more numerous under circumstances unfavourable to normal changes, as in inflammations), it seems very reasonable to infer that similar transformations of colourless into coloured particles are going on in the adult as in the embryo, and that the lymphatic and lacteal systems must be at least one, and that a fertile source, from which red corpuscles are being continually supplied to the blood."—Pp. 302-3.

There is no foundation for the idea that each blood-corpuscle gives origin by a species of reproduction to new blood-corpuscles. The blood-corpuscles probably decay by simple solution, though it does not yet clearly appear what substance in the blood, or in the body, results from their decomposition. The various colouring matters throughout the body have their origin, as is probable, from the colouring matter of the blood.

It is not unreasonable to suppose that the red corpuscles are floating gland-cells, as they are, in all essential points of structure, like the secreting cells of true glands. Their secretion is hæmatine; that is to say, not merely the colouring matter, but the entire contents of the blood-corpuscles, of which iron is probably an essential part, since even the blood of the invertebrate animals contains a sensible quantity of iron, and that when no colour is distinguishable.

Liebig's idea as regards the important function performed by the red particles, by means of the iron which they contain, must be spoken of when we come to the function of respiration.

Salts of the Blood.—With respect to the saline matters of the blood, the analysis we have given makes the proportion, estimated together with that of extractive matters, no more than about eight parts in the thousand, or somewhat less than one per cent. But, according to other analyses, this part of the blood amounts to more than one and a half per cent. The principal salts of the blood are the albuminate of soda; other alkaline salts, as the carbonate, phosphate, and sulphate of soda, and the chloride of sodium; earthy and metallic salts, as the phosphate of lime, the phosphate of magnesia, the phosphate of iron, the carbonates of lime and magnesia, and the peroxide of iron. In the muscular flesh, which constitutes the chief bulk of the living frame, and that, as before stated, which, from its activity, requires the most frequent repair, there is a considerably less proportion of saline matter than in the blood. Whence it may be inferred that, by the products of digestion, a larger amount of saline matter is thrown into the blood than is required for the nutrition of the chief solids; and therefore, that a great part of the saline matter given off from the blood by the kidney, is merely the excess of what has been received by the blood during digestion, and that it has never entered into the constitution of the living frame.

Some of the salts of the blood are essential to the secretions, particularly to the bile and to the gastric juice.

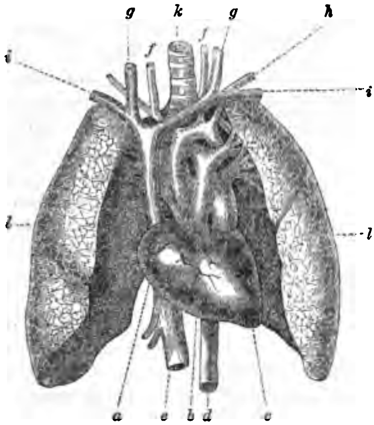
Waste and Repair.—The continual waste of the constituents of the blood is supplied by the products into which the food received into the stomach is converted. Together with the products of digestion, the contents of the lymphatic vessels, originating in almost every part of the living frame, are poured from the thoracic duct into the circulating system. Perfect chyle is collected from the small organs existing abundantly in the folds of the mesentery, termed mesenteric glands (see page 37), by vessels which gradually unite into a single trunk, by the union of which with the lymphatic trunks, from the pelvis and lower extremities, the thoracic duct, as already has been shown, is formed. The same general plan pervades the whole of the vertebrate division of the animal kingdom; that is, there is a lymphatic system of vessels pervading the body at large, and a chyliferous system of vessels originating in the intestines, both of which systems unite in a common trunk, which communicates directly with the sanguiferous system. In birds, reptiles, and fishes, however, there are no mesenteric glands. Although it cannot be doubted that important changes take place on such products of digestion as are taken up by the lacteals within the mesenteric glands, it is plain, from the fact just stated, that these organs are not essential to the formation of perfect chyle; that is to say, a chyle perfectly capable of imparting the required nutritive properties to the blood. One remarkable difference exists between the chyle in mammals, and that in the three remaining divisions of the vertebrata; namely, that in the former it is an opaque fluid, and throughout the latter quite transparent.

Lymph.—There is contained in the lymphatics, and also in the lacteals, when digestion is not going on, the transparent and almost colourless fluid termed lymph. In this lymph there are a number of colourless nucleated cells, which seem, as before hinted at, to be identical with the colourless corpuscles of the blood. In the chyle the same corpuscles are found; but, in addition to these, there is what has been termed the molecular base, a finely granular matter, which varies with the amount of fatty matter in the food. To the presence of this molecular base the milky colour of the chyle is said to be due. To the absence or deficiency of this substance is to be ascribed the transparency of the chyle in birds, reptiles, and fishes. If a dog be fed on food from which fat has been carefully excluded, the chyle is not milky, but whey-like or transparent.

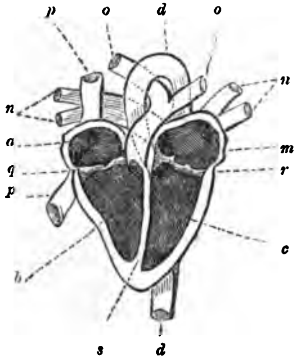
The molecular base is present in the chyle collected at the very origin of the lacteals in the intestinal canal. Both lymph and chyle, when taken from the vessels, undergo spontaneous coagulation. This coagulation depends on the presence of liquid fibrine, as in the blood; while the coagulability bears a close relation to that of the blood in the same animal. The serum of the lymph is an albuminous fluid. Saline matters of the same kind as exist in the blood are found in the serum of the lymph; there is also a trace of fatty matter and of iron. The coagulation of the chyle depends also on the presence of fibrine; and the serum of the chyle contains more albumen and more fat than the serum of the lymph.

Thus, lymph differs from blood, in having no red corpuscles, and having a less proportion of albumen and fibrine. Chyle differs from blood in the same respects, and also in containing a large proportion of fat, which may amount, it is said, to as much as one and a half per cent. Chyle differs from lymph in containing more albumen and much more fat. Of the fitness of the chyle, derived from the process of digestion, to sustain the nutritive properties of the blood, we have to speak hereafter. One point of difficulty arises, to explain what becomes of the large proportion of fatty matter which it contains. Fat is not a proteine compound; it cannot pass into fibrine, albumen, or caseine—it is a non-azotised principle; but though incapable of contributing to the repair of the more important textures, it is quite capable of supporting animal temperature by the process of slow combustion, termed eremacausis. It seems probable, then, that the superfluity of fatty matter supplied by the chyle to the blood is burnt off in the process of respiration, so as essentially to maintain the animal temperature.

What, then, is the use of the lymph which is poured so abundantly into the blood from the thoracic duct? As the lymph contains so many of the constituents of healthy blood, it is impossible to doubt that the addition of the lymph is a source of repair to the blood; but the question remains, What is the source of the lymph? By far the most probable supposition is, that the lymph of the lymphatic system is nothing more than the residue of the liquor sanguinis after the repair of the textures. The lymph is blood, deprived of the whole of the colouring corpuscles, and of part of its albumen and fibrine. The liquor sanguinis, or blood without the colouring corpuscles, exudes through the walls of the capillaries, and comes into contact with the ultimate morphological constituents of the tissues, which attract from it what is necessary for their repair; while, by the lymphatics, which are, in fact, a system of veins subsidiary to the red veins, the residue is conveyed to the thoracic duct, to be again mingled with the blood.



LUNGS, HEART, AND PRINCIPAL VESSELS IN MAN.

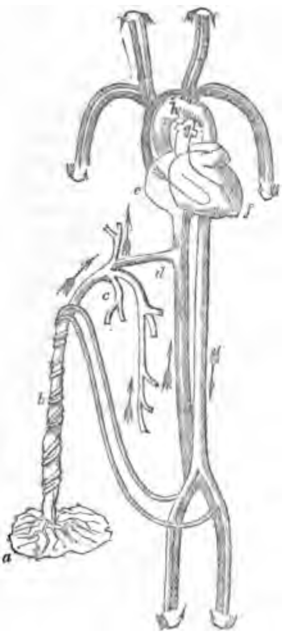


IDEAL SECTION OF THE HEART.

a, right auricle; *b*, right ventricle; *c*, left ventricle; *d*, aorta; *e*, vena cava; *f*, carotid arteries; *g*, jugular veins; *h*, subclavian artery; *i*, subclavian veins; *k*, trachea; *l*, lungs; *m*, left auricle; *n*, pulmonary veins; *o*, pulmonary arteries; *p*, superior and inferior venæ cavæ; *q*, tricuspid valve; *r*, mitral valve; *s*, partition.

From the view now exhibited of the composition of the solids, of the blood, and of the lymph and chyle, we obtain the means of judging of the important place held by the blood in the animal economy. The circulation—wonderful as it seems when considered merely in itself—is yet wholly subordinate in importance to the physiological constitution of the blood. It is a mechanical process, subservient, in certain classes of animals, to the uses of the blood; but the real wonder in physiology is the blood itself—its power of repairing the waste of the solids—and of repairing itself, at the expense of the food, through the medium of absorption. A brief notice, however, of the mechanism of the circulation, in the several orders of animals, must not be omitted.

The annexed diagrams of the circulating apparatus of man, after Carpenter, will enable us better to understand the details which follow. The heart, situated between the lungs, in the cavity of the chest, is somewhat conical. The lower end is quite unattached, and points towards the left; during contraction it is tilted forwards, striking the chest between the fifth and sixth ribs, and causing the "beat of the heart;" while the great vessels, rising from the upper and large extremity, being attached to neighbouring parts, seem to suspend the organ, and to allow its movements freely to take place. The heart in man is a hollow muscle, divided into four cavities, two on either side—the upper of which is termed the auricle, the lower the ventricle—the walls of the latter having, by their contraction, to propel the blood through a system of vessels, being thicker than those of the auricles, which have only to receive the blood from the veins, and transmit it to the ventricles. The circulation of the blood, then, is that process by which the fluid, setting out from the left ventricle of the heart, is distributed by the arteries to every part of the body, from whence it passes into the veins, is received from them into the vena cava, whence it returns to the heart, entering the right auricle, and passing into the ventricle on the same side, which propels it into the pulmonary artery, to be distributed through the lungs for purification. Thence it passes, by the pulmonary veins, into the left auricle, which transmits it again to the left ventricle, to repeat the course we have described.

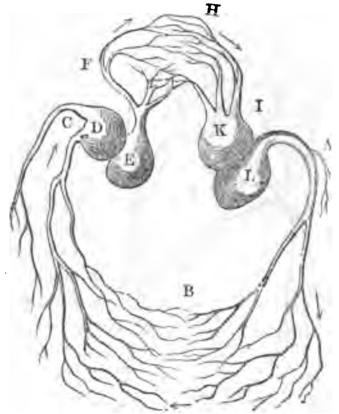


PLAN OF FŒTAL CIRCULATION—*after Wilson.*

a, placenta; *b*, umbilical cord, containing artery and vein; *c*, hepatic veins; *d*, inferior cava; *e*, right auricle; *f*, left ventricle; *g*, ductus arteriosus; *h*, aorta.

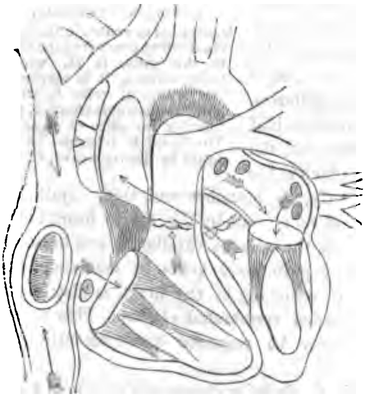
The circulation in the fœtus is conducted in a somewhat different manner. Commencing with the placenta, where the blood undergoes some change, analogous to that in the lungs of extra-uterine life, it is conveyed by the umbilical vein to the liver, and to the inferior vena cava; here it mixes with that brought from the lower extremities, and is carried directly through the right auricle into the left auricle by the foramen ovale, which, until birth, remains open, forming a direct communication between the two auricles; a portion only passes from the right auricle into the right ventricle, which contracting, the blood is sent into the pulmonary arteries; but respiration not going on, the greater portion of the blood passes directly through the ductus arteriosus into the aorta. The small portion of blood received by the left auricle from the lungs, as well as the greater portion passed through the foramen ovale, is transmitted into the left ventricle; by the contraction of which it is sent into the aorta, and by means of the umbilical arteries, which arise in the lower part of the abdomen, it is again returned to the placenta. It is a wonderful provision of nature, that, in the fœtus, where the lungs are not called into play, and are nearly solid and impervious, means should be provided to turn from them the great current of the blood—the whole of which, after birth, must pass through them, and to supply them merely with such a quantity as is necessary for their nutrition.

In the first two great divisions of vertebrate animals, mammals and birds, the circulation of the blood, with a few unimportant peculiarities, is performed on one plan. Of this plan, the most characteristic feature is, that the particular circulation through the lungs stands on the same footing as the general circulation over the rest of the body. It follows, from this condition, that no blood-corpuscle can circulate over the body more than once without having previously circulated through the lungs. The circulation, as it takes place in mammals and birds, is conveniently methodised under the two heads of the circulation of the dark-coloured blood, and the circulation of the red-coloured blood. The dark-coloured blood is properly described as appearing first in the venous capillaries, at every vascular point throughout the body. The organs, then, or cavities in which the dark blood is contained and moves, stated in their proper order of succession, are the venous capillaries over the body, ramifications of the veins, the venous trunks, the right cavities of the heart, namely, the right auricle and the right ventricle, the pulmonary artery,—the branches of that vessel and the corresponding capillaries. In like manner, the red-coloured blood is properly described as appearing first in the capillaries of the pulmonary veins; and the organs or cavities in which the red-coloured blood is contained and moves, stated in their proper order, are the capillaries of the pulmonary veins, the ramifications of the pulmonary veins, the trunks of the pulmonary veins, the left cavities of the heart—namely, the left auricle and the left ventricle—the aorta, or great trunk of the arterial system, the branches of the aorta, and the arterial capillaries. These two separate systems communicate, on the one hand, where the capillaries of the veins of the body join with the capillaries of the aortic system; and, on the other hand, where the capillaries of the pulmonary veins join with the capillaries of the pulmonary artery. The right and left sides of the heart, though in juxtaposition, are wholly distinct organs, and each heart is placed in the middle of its own system; the right being situated in the middle between the veins of the body and the pulmonary artery, and the left heart, between the system of the pulmonary veins and the system of the aorta.



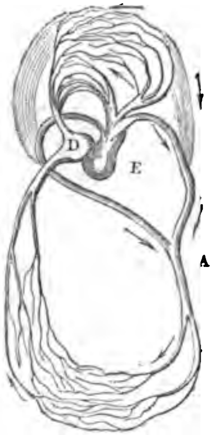
PLAN OF DOUBLE OR WARM-BLOODED CIRCULATION—*after Roget.*
A, aorta; B, system of arteries; C, vena cava. D, right auricle; E, right ventricle; F, pulmonary artery; H, lungs; I, pulmonary veins; K, left auricle; L, left ventricle.

The forces by which the blood is moved in the circulation are chiefly, if not exclusively, mechanical—the only force of much efficiency being the contraction of the cavities of the heart by a muscular effort, as the blood successively enters each; while valves are so placed as to permit its movement onwards, except in the proper direction only.



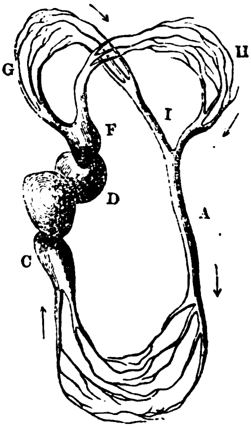
THE ANATOMY OF THE HEART IN SITU—*after Wilson.*
Showing its cavities, and tendinous and fleshy cords. The course of the pure blood through the left side of the heart is marked by arrows.

The plan of the circulation in the reptilia is somewhat different; and, though considerable varieties occur in the several orders of this class, one expression may be obtained to represent it throughout. Contrary to what is provided for in mammals and birds, a blood-corpuscle may circulate more than once over the body without passing through the lungs. The pulmonary artery and the aorta arise from one ventricle, that is, from the only ventricle, so that part of the blood derived from the ventricle passes through the lungs, and part is sent for general circulation over the body. This ventricle receives its blood partly from a systemic, partly from a pulmonic auricle—that is to say, part of the blood is dark coloured, and has reached the systemic auricle by the common veins of the body; the other part of the blood is red coloured, and has reached the pulmonic auricle from the pulmonary veins. Thus the only organs which contain red-coloured blood in the reptilia, are the pulmonary veins and the pulmonic auricle, while there are two other kinds of blood in the body, —namely, the proper dark-coloured blood contained in the veins of the body and the systemic auricle; and the mixture of dark and red-coloured blood first made in the single ventricle, and proceeding from it both to the pulmonary artery and to the aorta.



CIRCULATION IN THE BATRACHIA —*after Roget.*
E, ventricle. D, auricle. The aorta and pulmonary artery are seen arising from the ventricle, E, sending branches to the head and neck, and uniting to form a single trunk, A, the descending aorta. The blood is returned by the venous trunks to the auricle, D.

In fishes, the circulation of the blood presents a singular peculiarity. There is but a single heart present—that is, a heart consisting of only two cavities, namely, an auricle and a ventricle, and these cavities correspond, not to the left or systemic heart of mammals and birds, but to their right or pulmonic heart. It is to be remembered that, in fishes, the gills take the place of lungs. Provision is made, in fishes as in mammals, that no blood-corpuscles shall circulate more than once over the body without previously passing through the respiratory organs. Also, in fishes there are but two kinds of blood, the dark-coloured and the red-coloured blood. The cavities containing the dark-coloured blood are the venous capillaries of the body, the venous trunks, the two cavities of the single heart, the branchial artery, its ramifications and capillaries. The cavities containing the red-coloured blood are branchial venous capillaries, the branches formed from them, and the trunk formed in the next succession from them, which is the aorta, or proper artery of the whole body; lastly, its branches and their capillaries. Thus the peculiarity in fishes is, that the dark blood is sent by the single heart to the gills for purification; and, being re-collected from the gills by capillaries and branches corresponding to the capillaries and branches of pulmonary veins in mammals and birds, passes at once into a trunk which, without returning to the heart, is distributed over the body like the aorta in the two warm-blooded vertebrated classes. This trunk, formed from the branchial venous branches, may be regarded as representing, at once, the pulmonary vein and the aorta.

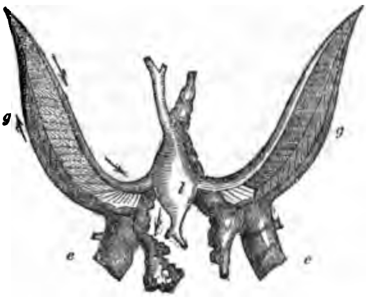


CIRCULATION IN FISHES.
D, auricle; C, ventricle; F, branchial artery conveying the blood to the gills, G H, where, being aerated, it is carried by the branchial veins I, which unite unto a single trunk, A, performing the office of an aorta. The blood is returned to the heart by the vena cava, C.

With respect to the circulation of the blood in the inferior classes of the animal kingdom, it will be sufficient to select a few examples, as we shall next proceed to do, without attempting to exhaust the whole subject within the narrow limits to which this treatise must be confined.

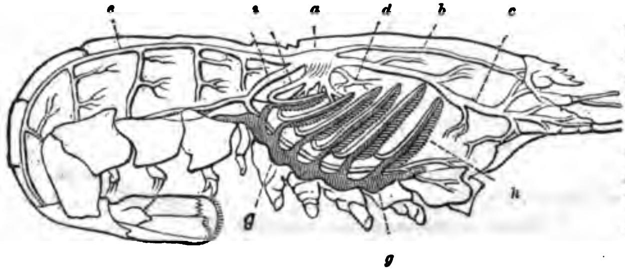
◆

Among the molluscs, the circulation of the blood in the cuttle-fish has a remarkably perfect character. In this animal there are three separate hearts at some distance from each other. Each of these, however, has only one cavity. In short, each of the three is a single ventricle. The cuttle-fish breathes by gills. There are only two kinds of blood, the dark-coloured blood and the red-coloured blood. The organs which contain the dark-coloured blood are the veins of the body, and the two trunks which they form; the two separate hearts, subservient to the circulation respectively of the two gills; the two branchial arteries and their ramifications. The organs which contain the red-coloured blood are the ramifications and the trunks of the two systems of branchial veins, and the systemic heart, or ventricle, in which these two systems terminate; also the aortic system arising from the systemic heart. The middle, or systemic heart, transmits the red-coloured blood by the aorta and its ramifications all over the body; the blood, having become dark-coloured, is carried from the terminations of the aortic system by the veins of the body in two portions to each of the two lateral or pulmonic hearts; from each lateral heart the blood is propelled to the gills of one side, whence, having become red-coloured, it is carried again to the middle systemic ventricle.



CIRCULATION IN THE CUTTLE-FISH—*after Audouin.*

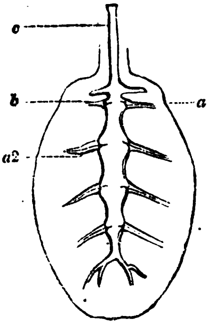
e e, lateral or branchial hearts, conveying the blood to the gills *g g*, whence it is returned to *l*, the central or systemic heart, for general distribution.



CIRCULATION OF THE LOBSTER.

a, heart; *b* and *c*, arteries of eyes and antennæ; *d*, hepatic artery; *e* and *f*, arteries of thorax and abdomen; *g g*, great venous sinus; *h h*, the gills; *i*, branchial veins.

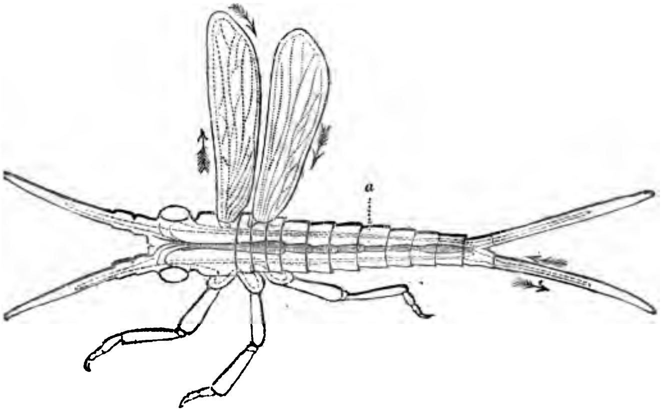
Among the Crustaceans, the circulation of the lobster has been particularly studied. In it the heart has a single cavity or ventricle; and from this heart several large arteries are derived, by which the blood is conveyed to all parts of the body; but from one of these arterial trunks branches are given off, which proceed to the gills. The blood is brought back from the several parts of the body by proper veins, and from the gills by branchial veins, and the blood from these two sources mingles in a common cavity, or sinus, before it re-enters the single ventricle, to be again sent forth. Thus in the lobster there are three kinds of blood,—the red-coloured blood, dark-coloured blood, and the blood composed of the dark and red blood mixed together. The red-coloured blood is contained only in the system of the branchial veins; the dark-coloured blood is contained only in the veins of the body; the mixed blood in the venous sinus, or sinuses, where the two kinds mingle before entering the heart. This mixed blood is contained in the heart and in the arterial or aortic system, and also in the branchial arteries sent off from the aortic system.



CIRCULATION IN SPIDERS—*after Carpenter*.
a, the abdomen; *a2*, large dorsal vessel, or heart; *c*, trunk passing to head; *b*, vessels communicating with respiratory organ.

In the spiders with pulmonary cavities—that is, with pulmonary organs limited to one part of the body—there is an elongated dorsal vessel, which gives off arteries and receives the terminations of veins; the action of which seems to be to drive the blood at once to the several parts of the body, and also to the pulmonary organ. The purified blood from the pulmonary organ must mingle with the blood returning from the several parts of the body in open spaces, or sinuses, whence, by the branchio-cardiac vessels or veins, it reaches the dorsal heart.

In insects, the circulation of the blood proceeds on a plan altogether peculiar. There is a large dorsal blood-vessel, or heart, provided with apertures and valves, and capable of contraction, but without ramifications,—in short, in insects there is a heart, but no blood-vessels; and since the air, by the air-tubes extending from the surface, has access to all parts of the body, there is only one kind of blood, namely, the arterial. The dorsal heart extends nearly the whole length of the insect's body; it is open at the anterior extremity, and by this open part the blood issues to diffuse itself over every part of the body. The contractions of this vessel, or heart, begin at the posterior part, are propagated forwards, so that the contained fluid is pushed from the tail towards the head. Within the vessel are valves, by which it is divided into compartments, so placed that the fluid can pass forwards, but not from before backwards. The several compartments communicate on each side by lateral slits with the cavity of the belly, and these slits are



CIRCULATION IN INSECTS.
a, the great dorsal vessel.

provided with valves, so that fluids can enter from the belly, but cannot again issue from the vessel otherwise than by the opening in front. The nutritive fluid prepared in the intestine percolates through its walls, and mingles with the blood diffused over the body from the anterior openings of the heart; and this mixture of blood and the product of digestion passes into the heart by the lateral openings.

In some of the Radiata a circulation of the blood is admitted; but in this part of Physiology there are too many points of controversy to accommodate it to our limits.

On the Renovation of the Blood by Chyle and the other Products of Digestion.—As the blood is unceasingly drawn upon for the repair of the constant waste of the solids and fluids of the body, there is a clear necessity for its continual renovation. Of this renovation the most obvious source is the supply afforded of lymph and the products of digestion, chiefly by the thoracic duct, which, as we have seen, communicates with the venous system at the upper part of the chest, on the left side.

The most probable opinion as to the origin of the lymph is, as we have seen, that it is the residue of the liquor sanguinis, returned after nutrition from all parts of the body to be again mingled with the torrent of the circulation. But whatever its real origin, it must be, in any event, derived wholly from the blood, so that it cannot be set down as an independent source of renovation to that fluid. The chyle, however, does unquestionably contain matter which is independent of the blood, as never having formed any part of that fluid. The chyle is indeed the only distinct organic fluid bearing that character. It cannot, however, be affirmed that the chyle consists wholly of materials derived from without, and that no part of its constitution has been drawn from the blood. It may be regarded, on just grounds, as a general rule of organic nature, that the nourishing matter obtained from without does not become fit to be incorporated with the living solids, until it has united itself with materials prepared within the organism, and derived from the proper substance of the living agent.

We have already traced the chyle to the food which is received into the stomach. In the healthy body that food undergoes a complete transmutation; and until lately it has been universally believed that the chyle and the feculent matter discharged from the lower bowel are the sole products of that transmutation. Doubts have arisen, on grounds to be stated presently, whether the chyle and the fæces are the sole products of the transmutation of the food in digestion. It is certain, however, that these are at least principal products of that process. However this may be, it is to be remarked that the food is not exclusively the material which undergoes transmutation. The chyle and the fæces are the result, whether exclusively or together with other products of the transmutation, of a mass, consisting of the food, mingled with several remarkable organic agents derived from the blood, such as the saliva, the gastric juice, or the proper secretion of the stomach; the bile, the proper secretion of the liver; and the pancreatic liquor, the proper secretion of the sweetbread.

If the food be exclusively divided between the chyle and the fæces, whatever of the mass of food which does not find its way into the feculent discharge, must enter into the constitution of the chyle. Thus, from the character of the feculent mass, some notion may be gained of the relation subsisting between the food and the chyle.

By weight the feculent mass discharged in twenty-four hours equals nearly one-sixth part of the average daily quantity of food. The solid part of the discharge amounts to about twenty-seven per cent. of the whole, the rest being water, namely, seventy-three per cent. The twenty-seven per cent. of solid matter may be distributed as follows:—Insoluble matters derived from the food, seven per cent., insoluble matters derived from the bowels, liver, &c., fourteen per cent.; soluble matters, consisting of bile, albumen, extractive, and salts, six per cent.

Thus, in the fæces, the nutritive proximate elements of organic matter, as already referred to, have almost entirely disappeared; there being nothing of that description in that account, except less than one per cent. of albumen, while the average amount of nutritive matter in the substance of a meal can hardly be estimated at less than fifteen per cent. Two important facts here deserve particular remark,—the small proportion borne by the fæces in weight to the average amount of food, and the minute proportion of nutritive matter which that fraction contains.

Thus, if the chyle and the fæces be the sole products of the transmutation of the alimentary mass in the digestive organs, the chyle must take up nearly all the nutritive matter contained in the food, as well as much of what is not accounted nutritive, together with no small proportion of the matters secreted by the several organs concerned in digestion.

Thus, on the supposition made, if the daily amount of food be estimated at twenty-five ounces, the quantity of chyle which passes daily into the blood must bear a very large proportion to that quantity, and to the nutritive substances, or their products, which that quantity contains.

In estimating the comparative quantities of fæces and chyle, it must not be forgotten that the chyle is more watery, containing about ninety per cent. of water; so that twenty-one ounces of chyle contain no more solid matter than nineteen ounces of fæces. As six or eight ounces of chyle may pass through the thoracic duct in one hour, it is not impossible to believe that from twenty to thirty ounces may pass through that vessel into the blood, in repeated portions, throughout the twenty-four hours. The great quantity of the chyle required to support the common view, hardly tells to its prejudice. But numerous experiments seem to show that true chyle—that is, the fluid found in the lacteal vessels and the thoracic duct, at a certain period after food has been taken, and at no other time—does not contain the chief nutritive parts of the food, or their products; so that it is forced on the physiologist to consider whether these chief nutritive constituents of the food can make their way into the blood by any other channel.

The transparent fluid found in the lacteals during fasting has very much the same characters as the lymph of the lymphatics. The transparent contents of the lacteal vessels, and the contents of the lymphatics, alike coagulate, on standing, into a slightly coherent jelly. This property depends on the presence of fibrine in a fluid form, as in the blood. When white chyle is drawn from the lacteal vessels, or from the thoracic duct, along with the constant transparent contents of these vessels a coagulation takes place; but this coagulation is plainly due to the coagulation of the transparent fluid, by which certain particles proper to the chyle are entangled. The white chyle itself contains no fibrine; it consists, as it would seem, exclusively of fatty matter in a state of extreme subdivision.

To recapitulate these facts:—

1. There is at all times in the lacteal vessels a fluid exactly similar to what exists in the lymphatics throughout the body.

2. This fluid, common to both kinds of vessels, coagulates, owing to the presence of fibrine.

3. There is no more fibrine in the fluid collected from the lacteal vessels, when they have acquired a white colour after a meal, than when they are colourless.

4. After the longest fasting, there is still found in the lacteal vessels a coagulable transparent fluid, containing the same amount of fibrine as the lymph.

5. If an animal be fed on food from which all fat has been carefully separated, the fluid in the lactals does not acquire the white colour seen under other circumstances after a meal.

6. When an animal is fed on food free from fat, there is a marked difference in the state of the lacteals, their contents being either wholly or nearly free from the white colour.

It hence appears necessary to assume, contrary to the long received opinion, that there are other products of the transmutation of the food, mingled with the secretions before enumerated, than chyle and the feculent mass, and the next step is to seek positive evidence in favour of such an assumption.

It is undeniable that fibrine, albumen, caseine, and the like, are contained in the food. What, then, has become of these constituents of the food, if they be found neither in the chyle nor in the feculent mass, either in their original form or in a transmuted state?

On this point we shall quote a passage from a work of high authority in Physiology, in preference to expressing this great deviation from the received view in our own words. The passage, however, may require one or two words of previous explanation.

It has already been explained that the whole alimentary canal, from the mouth to the extremity of the rectum, is lined by mucous membrane. On that part of the mucous membrane which forms the lining of the small intestines, and quite peculiar to that portion of the mucous membrane, there are minute processes termed *villi*. These processes are very numerous, giving to far the greater part of the inner surface of the small intestines an appearance like that produced by the pile of velvet. Their length in man is from one-sixtieth to one-forty-fifth of an inch. Each villus is covered by epithelium. The cavity of each villus, besides blood-vessels, contains one or two small lacteals. The villi become turgid during ordinary digestion; the epithelium, which closes each cavity, is either wholly detached, or becomes turgid with the matters passing inwards to the cavity of the villus. After this explanation of the nature of a villus, we cite the passage to which we have referred :—

MAGNIFIED SECTION OF THE MUCOUS MEMBRANE OF A DOG—*after Brunner*. Showing the villi, or absorbing tubes; beneath them the follicles of Lieberkühn, and other coats of the intestines.

"It was evident in these experiments that the marked contrast between the state of the contents of the lacteals, and the condition of the villi, was connected with the presence or absence of fat in the food, and that so long as the food was purely albuminous or fibrinous, or mainly amylaceous, the chyle was transparent, and the villi apparently inactive; but that the addition of fat to the food called the villi into activity, and filled the lacteals with an abundant milky chyle.

"Are we to infer, then, that the lacteals absorb fatty matters only, and that the villi are altogether inactive, save when fatty or oily matters are to be absorbed? We apprehend that such an inference is not justifiable. It may, however, be concluded that the villi and the lacteals are capable of absorbing all substances which the blood-vessels absorb, and by a simple process; but that the absorption of fatty matters devolves upon them only, and is a more complex process, involving considerable changes in their tissue.

"And upon similar grounds we may conclude, that while albuminous and fibrinous aliments contribute to the formation of chyle, they do not necessarily undergo the change into chyle in order to be absorbed. But fatty matters appear to admit of absorption in no other way, except by a reduction to the state of molecular base of the white chyle.

"These observations and experiments denote sufficiently clearly that two channels exist for the transmission of the nutritious matters from the intestines to the blood; one through the lacteals to the villi; the other directly through the walls of the blood-vessels themselves. Matters taking the latter route must pass through the liver, and would be subjected to the influence of that gland before they reach the *inferior* vena cava and the right auricle, while those passing through the former channel must permeate a totally distinct system of vessels, namely, the lacteal system, to be conveyed to the *superior* vena cava, and to the right auricle, where, having mingled with the blood coming from the liver, both are transmitted by the right ventricle to the lungs. And it would seem that the object of the two modes of absorption at the intestine, and of the two paths of transmission from the intestine to the centre of the circulation, is to keep separate, up to a certain point, two kinds of material resulting from the digestion of the food. And probably the reason why one kind of product is reserved to pass through the intricate capillary plexures of the vascular system of the liver, to the exclusion of the other, is because it contains material out of which the liver may elaborate bile, whilst the other material is transmitted through a less complicated series of channels more directly to the lungs."—*Physiological Anatomy*, by Todd and Bowman, p. 245.

It seems impossible, then, to evade the conclusion that the renovation of the blood is not due solely to the supply conveyed to it by the chyle; and that a most important part of that which digestion prepares for the repair of the circulating nutritive fluid is derived directly by absorption from the internal surface of the stomach and intestines. Under this view all the products of the transmutation of the mass of food and the mingled secretions, except the chyle and feculent matter, pass through the circulating system of the liver; since the veins of the stomach, as well as the veins of the intestines, contribute their blood to the contents of the portal vein, which, in its course through the liver, secretes the bile.

When the small amount of the feculent discharge—not exceeding six ounces in twenty-four hours—is compared with the quantity of food received into the stomach in the same period, augmented as it is by admixture with the saliva, the gastric juice, the biliary discharge, and the pancreatic liquor, it is seen that no inconsiderable proportion of new material is transmitted daily from the alimentary canal into the current of the circulation for the renewal of the blood, and to fit it for the several offices which it has to perform. The aggregate of these several secretions mingled with the food, must far exceed the average weight of the feculent discharge. The quantity of bile alone, secreted in twenty-four hours, must exceed the amount of the feculent discharge. The quantity of bile afforded to the duodenum in twenty-four hours has sometimes been carried far beyond this estimate; for example, to the extent of from seventeen to twenty-four ounces; but more exact observations show that from six to eight ounces come nearer the truth.

Thus, at the most moderate calculation, the blood receives daily a quantity of material for repair equal to the whole weight of the food taken into the stomach. As, however, the secretions with which the food is mingled in digestion, are a direct tax on the blood, it may seem more correct to estimate the daily addition to the blood simply at the weight of food taken into the stomach, diminished by the weight of the feculent matter; so that the average daily addition to the blood by digestion may be taken at from twenty to thirty ounces.

The food, as we have seen, consists of the same chemical elements as the solids of the body and the blood itself; so that the supply of renovation which the system daily receives permits a corresponding loss—let us say of about twenty-five ounces of its substance. This knowledge marks a great era in the progress of Physiology. It is the triumph of the Physiology of our day to have shown the exact accordance between waste and supply in the animal economy; to have shown, on the one hand, the harmony between the chemical composition of the various solids of the body and the chemical composition of the blood; and, on the other hand, the harmony between the chemical composition of the food and the chemical composition of the blood.

A few words are necessary, in addition to what was said in an earlier section of this treatise, on the changes which the food undergoes before it becomes fit to be received into the blood.

The alimentary canal consists of a succession of hollow organs, in which peculiar changes occur. The first change which takes place is the admixture of food with saliva under the act of mastication. The saliva contains less than two per cent. of solid matter, the rest being water. This solid matter consists of organic substances and salts. Part of the organic matter is composed of epithelium which has separated from the mucous membrane of the mouth; the rest is a peculiar matter, to which the name of plyalin has been given. It is probably nothing more than a species of animal extractive, common to many fluids in living bodies. Among the salts found in the saliva, one deserves particular notice—namely, the sulpho-cyanide of potassium, which gives a red tinge with persalts of iron.

In the stomach the gastric juice effects important changes. This fluid has the property of dissolving flesh and other articles of food out of the body when a proper temperature is preserved; and an infusion of the mucous membrane of the stomach, with the addition of some acid, such as the muriatic acid, has the same effect—a property, although in a slighter degree, also possessed by the mucous membrane of the duodenum, but not by mucous membrane taken from other organs of the body. It has hence been supposed that a peculiar organic principle, to which the name pepsin has been bestowed, exists in the gastric juice, and is the proper agent in those effects; but which, however, has not yet been separated in a distinct form. No mere acidulous solution acts in this manner on aliment. The solution of the chief animal nutritive principles by the gastric juice is so complete, as to create no difficulty in the hypothesis that the dissolved matters may pass at once into the veins of the stomach.

In the duodenum, which is a species of second stomach, the mass which has descended from the stomach, termed chyme, is subjected to the influence of the bile from the liver, and of the pancreatic juice from the sweetbread.

The Bile.—The analysis of the bile has caused much trouble to chemists. It is an animal soap. The peculiar substance which it contains is named bilin. Besides this, there are salts, mucus, and ninety per cent. of water. According to other views, bile is essentially a solution of a salt of soda, formed by combination of the base with two peculiar acids—namely, the cholic acid and the choleic acid; the latter acid containing sulphur.

The following extract from the work already quoted, exhibits an excellent summary of the latest conclusions as to the uses of the bile :—

"1. That it secretes a highly complex fluid, which is poured into the intestinal canal, and there undergoes decomposition. Its colouring-matter (cholephyrrhin, or biliverdin) is carried off in the excrements, and may possibly assist in stimulating the action of the intestine. Its fat is in great part, at least, absorbed by the villi. So much of its fat as is not thus acted upon contributes to form the fæces. Its salts, also, are probably carried off in the fæces. Other of its elements contribute to the digestive process, by promoting the solution in the bowels of some kinds of food which have escaped the solvent action of the gastric fluid. What these elements are, and what kinds of food they serve to dissolve, we have yet accurately to determine; it seems certain, however, that it exercises no solvent power over fatty or oily matters, and probable, that it acts upon azotised matters.

"2. The liver forms sugar and fat by chemical processes in its circulation, independently of any direct or immediate supplies of these substances in the aliments.

"3. The liver is a great emunctory; it eliminates carbonaceous matters, some directly, as the colouring-matter of the bile, which is at once thrown out in the fæces; others indirectly, as fat and sugar, which, passing to other parts of the circulation, are more or less acted on by oxygen and eliminated as carbonic acid and water.

"4. The liver contributes largely to the maintenance of general nutrition; first, by aiding in the solution of certain aliments in the intestinal canal; and secondly, by furnishing food to the calorifacient process."—(*Op. cit.*, p. 263.)

Pancreatic Liquor.—The pancreatic liquor is a colourless limpid fluid, viscid and gluey. It has an alkaline reaction, and is never acid or neutral. It coagulates by heat like white of egg, becoming completely solid. The coagulable principle of the pancreatic liquor resembles albumen, but is not identical with it. The pancreatic liquor, or a piece of the pancreas itself, transforms starch into sugar; and its peculiar property is that of digesting, by a peculiar modification, all the neutral fatty matters met with in the food. When olive oil is mixed with fresh pancreatic juice, and the mixture thoroughly agitated, a perfect emulsion is formed, and a liquid similar to milk or chyle results. No other animal fluid possesses this property. The pancreatic liquor, then, seems designed for the special digestion of oils and fat.

Such, then, are the agencies by which the food is prepared to mingle with the blood for its renovation.

On the Purification of the Blood.—We have seen that the new products supplied to the blood in the process of digestion, take two channels into the venous system—part passing along with the venous blood gathered from all the organs concerned in digestion, to be sent through the liver for the secretion of bile; part passing by the lacteal vessels and the thoracic duct to a vein in the upper part of the chest, so that it is transmitted directly to the right side of the heart, and thence, still along with venous blood, sent through the lungs.

The blood is purified, after the admixture of the new supplies, by the liver and the lungs; hence the liver and the lungs have sometimes been named the Great Emunctories of the blood. A third great emunctory has to be added, namely, the kidney. By these three organs the blood is purified, and rendered fit for the maintenance of the several organs and parts in a state of health.

The Liver.—It is unquestionable that the liver secretes a fluid—namely, the bile—which is of essential service in the process of digestion; but there are, nevertheless, the best grounds for the belief that by the act of preparing this secretion, the liver separates something which, if retained, would prove injurious.

The liver, or at least a biliary apparatus, appears in a rudimentary form in insects and spiders; it puts on a higher development in the crustaceans, as in the lobster; and in molluscs, as in the cuttle-fish, the snail, the oyster, and the like, assumes a character very much resembling what it possesses in the higher animals. In the vertebrated animals it preserves an aspect similar to that which it has in man.

In man the liver is a large organ, being the largest gland in the body, and has a very complex structure—in particular, a peculiar arrangement of the blood-vessels. There is, as in the other organs, an artery termed the hepatic artery, and veins termed hepatic veins. It is a rule throughout the body, that veins are larger than the corresponding arteries. But the hepatic veins exceed the capacity of the hepatic artery far beyond the measure assigned by this rule. Why this should be, will readily appear. The liver has a blood-vessel, to which there is nothing correspondent in the other organs of the body—a vessel which, though it conveys venous blood, is distributed like an artery throughout the substance of the liver. In the first place, then, it is manifest that the large size of the hepatic veins arises from the circumstance that these veins convey to the great venous trunk of the abdomen, not only the blood transmitted to the liver by the hepatic artery, but also that transmitted into it by this peculiar vessel, which carries venous blood by its ramifications throughout the liver. In short, it is found that the hepatic veins correspond not merely to the hepatic artery, but to the three great arteries which come off azygously—that is, without fellows, or not in pairs, but singly—from the anterior part of the abdominal aorta. These three arteries supply the stomach, the bowels, the spleen, the pancreas, and the liver itself, with their proper branches. The veins corresponding to the ramifications of these arteries, instead of proceeding at once to the great abdominal venous trunk, unite together successively to form what is termed the portal vein, or that great vein which enters the liver and is distributed like an artery. From the minute ramifications of this vein, the bile is secreted, while the residual blood is taken up by the minute radicles of the hepatic veins.

It remains to be explained that the blood of the hepatic artery nourishes the liver, and having therefore become venous, is poured by its minute ramifications into the minute divisions of the portal vein, from which the bile is secreted.

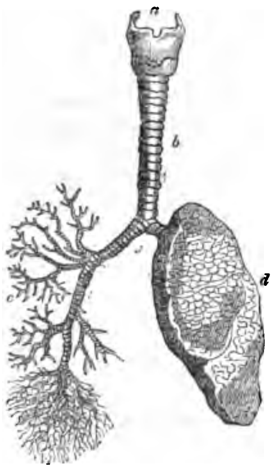
Thus, the bile is not secreted from the arterial blood of the hepatic artery, mingled with the venous blood of the portal vein; but the portal vein, being previously supplied with the venous blood produced in the nutrition and secretions of all the organs concerned in digestion, is finally reinforced by the venous blood produced in the nutrition of the liver itself and the gall bladder. Thus, as was already stated, the hepatic veins, the radicles of which communicate directly with the minute divisions of the portal vein, return to the great venous trunk of the abdomen all the blood sent out by the three arteries named the cœliac, the superior mesenteric, and the inferior mesenteric.

And this arrangement prevails throughout the order of mammals; while in the rest of the vertebrated orders a vein corresponding to the portal vein is formed by the union of veins derived from the pelvis as well as the abdomen, and supplies the kidneys as well as the liver.

The Lungs and Respiration.—As the liver at once produces a fluid subservient to digestion, and effects a certain purification of the blood, so the lung performs a most important office of purification of the blood, while by that same act it further generates the heat necessary for the maintenance of animal temperature.

It is clearly established by chemical evidence, that whenever carbonic acid is formed by the union of carbon and oxygen, heat is generated. With the air thrown forth in expiration a large proportion of carbonic acid gas is mingled, while the air taken in by inspiration contains no more than a minute proportion of that gas. The organs of respiration, indeed, in all animals, are continually engaged in throwing off from the system carbonic acid gas. During this process of respiration, on the other hand, a quantity of oxygen gas is continually disappearing from the surrounding air. The air which passes into the lung in inspiration contains about twenty per cent. of oxygen; the air which comes forth in expiration contains but a very small proportion of oxygen gas, the place of which is nearly supplied by the carbonic acid gas already spoken of. It has been already shown that a large proportion of carbon exists in the constituents of the body, as well as in the food daily taken into the stomach; hence it is impossible to doubt, when joint reference is made to these several facts, that a slow combustion goes on somewhere within the lung system, by which carbon and oxygen are united into carbonic acid, while, as on every such occasion, heat is produced.

Such, then, is the essential character of the function of respiration in the animal kingdom—the purification of the blood by a slow combustion of carbon, while that same combustion maintains the animal temperature.

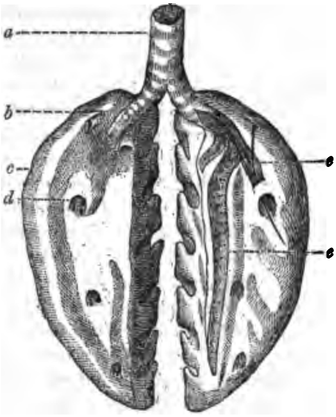


AIR-TUBES AND LUNG IN MAN.
b, trachea or windpipe, opening at the back of the mouth by the larynx, *a*; *c*, dissected air passages or bronchial tubes; *d*, lung in its natural state.

In mammals the mechanism of respiration proceeds on a pretty uniform plan. Even in the cetaceous animals, or whale tribe, the variations consequent on their mode of life hardly affect the essential type, being of a subordinate character. In whales, however, the efficiency of the function of respiration for the generation of heat is particularly exemplified. They live in a medium which abstracts heat from the surface in a far more rapid ratio than air, and most of the tribe live in the very coldest seas. nevertheless, their temperature rather exceeds that of man and mammals in general.

The mechanism of respiration in mammals it is not difficult to understand. The lung is an extensible elastic air-bag, enclosed in the cavity of the chest (see p. 61). In that cavity the lung hangs nearly free—that is, the surface of the lung is, with slight exception, simply in contact with the inner wall of the chest, without adhering to that wall. The lung alone communicates with the external atmosphere, there being no passage by which air can penetrate into the cavity of the chest—that is to say, by which it can insinuate itself between the outer surface of the lung or air-bag, and the inner surface of the wall of the chest. The walls of the chest close in above around the windpipe, which is of narrow diameter, ascending from the lung to reach the mouth. By the windpipe the air freely enters every part of the healthy lung. The lung, or bag of air, of necessity fills the actual cavity of the chest, and applies its outer surface close to the lining membrane of the cavity; because, were any part of the lung to collapse, or withdraw itself from the wall, a vacuum would be produced; but such a vacuum is impossible, so long as the lung is everywhere freely extensible, and the air has free access, through the air-tubes connected with the windpipe, to every part of the lung. The lung itself is passive, or nearly passive, in respiration. The chest is capable of alternate expansion and contraction. This alternation of change on the capacity of the chest is produced by muscular contraction, assisted in expiration by the elasticity of certain parts. The expansion of the chest is wholly a muscular act, and its contraction, when moderate, is altogether dependent on the physical properties of its walls. When the chest expands, the lung or air-bag closely follows, being dilated in exact proportion as the chest expands. When the chest contracts its cavity, the lung or air-bag being compressed, still exactly fills the chest, while the superfluous air is thrown out. When the chest expands very slowly, the air may enter as fast as the lung dilates, and then no appreciable rarefaction can take place on the air throughout the air-cells. But when the chest expands rapidly, the air cannot enter by the windpipe fast enough to keep pace with the dilatation of the lung. Why, then, does the lung dilate also in this case? Plainly owing to the universal tendency of air to dilate when previous pressure is diminished. This is an important point in the mechanism of respiration, because this tendency in air to dilate and distend an extensible bag like the lung, counteracts the atmospheric pressure on the external walls of the chest, and much facilitates the further enlargement of the chest. Whenever, then, in inspiration the chest expands somewhat rapidly, the air throughout the lung proportionably expands by its dilatibility on the removal of pressure, and therefore becomes rarefied, so that it is no longer equal to the support of the weight of the atmospheric column, which therefore descends by the windpipe, until an equilibrium is restored. Authors frequently term the dilatibility of the air on the diminution of pressure, elasticity. This is not absolutely incorrect, but it plainly creates confusion. When air is compressed beyond the density at which it exists under the ordinary atmospheric pressure, the recovery of its former volume is properly ascribed to its elasticity. But as conventionally we speak of bodies in general as being solid, liquid, or aëriform, according as they exist in any one of these states under the ordinary atmospheric pressure; so, if elasticity be defined that property by which a body recovers its former volume when compression is removed, we should refer to the expansion of air, when the ordinary atmospheric pressure is diminished, by another term than elasticity, as that implies a return to some condition other than that under which it exists in the circumstances prevailing at the earth's surface.

In birds respiration is more energetic than in mammals. The temperature of their bodies is somewhat higher—that of mammals being rather below 100° Fahr., while that of birds is often some degrees above that point. The lung or proper air-bag of birds is not larger proportionately than the lung in mammals; moreover it is fixed, hardly dilatible, and does not fill the whole cavity in which it is contained, like the lung of mammals. But in birds the air penetrates to almost every region of the body, and particularly into the abdominal cells, which freely communicate with the divisions of the windpipe. The whole trunk, in short, forms one great respiratory cavity; and when the expanded breast-bone is drawn downwards from the vertebral column, acting like a great bellows, it sucks air into the whole cavity, and by its ascent again expels it Birds have no proper midriff or diaphragm, by which, in mammals, the chest is closed in below, and divided from the abdominal cavity.



AIR-TUBES AND LUNGS OF BIRDS.
a, trachea; *b*, pulmonary vessels; *c*, lung; *d*, orifice of bronchial tube; *e*, bronchial tube opened.

In reptiles the respiration is of a much less energetic character than in mammals and birds. These animals are consequently cold-blooded: that is, their temperature nearly accords with that of the medium in which they live.

The lungs, however, are generally of great size in reptiles, as compared with the bulk of the whole frame. The pulmonary cells are much larger than in mammals and birds, and sometimes the lung degenerates into a mere membranous bag without partitions. As the lining of the minute air cavities in the higher animals is the membrane in which the blood is subjected to the influence of the air, it follows that the smaller the air-cells are the greater is the extent of the tissue in which the blood is exposed to the action of the air; so that, notwithstanding the size of the lungs in reptiles, a much smaller proportionate quantity of blood is brought into contact with the air in a given time than in the higher orders of animals; since they, in the aggregate, have a most extensive lining to the interior of the air-cavities, owing to their very minute subdivision.

In a few reptiles respiration takes place by gills, as in fishes. The Perennibranchiate amphibia, as they are named—of which the Lepidosiren is an example—possess both lungs and gills. The frog in the tadpole state breathes by gills; in the mature state by lungs. In the frog, as in some other reptiles, inspiration is performed on a plan altogether different from what is observed in the higher orders, and the air may be described as being swallowed. The mouth is very capacious. The jaws are first closed, and then the mouth being dilated, the air enters by the nostrils and distends it then by the compression of powerful muscles, while the nostrils are closed by valves, the air is forced to descend into the lung. It is subsequently expressed, as in the deep expiration of the higher animals, by the action of the abdominal muscles on the chest.

In fishes breathing takes place solely by gills. The water which is impregnated with atmospheric air is taken in by the mouth, and forced out again by the apertures on each side of the neck. It is thus made to pass between the gills, which form a set of comb-like vascular fringes, supported upon a system of bones termed the branchial arches. These arches are generally four in number on each side, and are attached by one extremity to an intermediate chain of bones situated opposite the middle of the neck, behind the hyoid bone, while by their opposite extremity they are joined by ligaments to the under surface of the skull.

A branchial arch is made up of several pieces joined together by ligaments, the whole being perfectly flexible, and the edges defended by little osseous plates, commonly armed with teeth; and the arches are so placed as to prevent the food taken into the mouth from being forced out through the branchial fissures with the stream of water.

The function of respiration is manifestly the same in fishes as in the higher animals, namely, purification of the blood and the maintenance of animal heat.

Of molluscs the chief part breathe by gills; some however breathe air by organs corresponding to lungs.

The cephalopods, as the cuttle, nautilus, &c., have two gills, one on each side of the muscular sac formed by the cloak. These gills have the form of a compound fern leaf, and are contained within the visceral sac. The water enters through a valvular aperture, and is subsequently expelled with force through the funnel.

Of the gasteropods, the terrestrial species, such as the slug, snail, limpet, and welk, breathe air which is alternately drawn in and expelled from a cavity lined with a vascular network. To these species the name Pulmobranchiata has been given. All of these do not absolutely live on land, but such of them as inhabit the water must frequently rise to the surface for the purpose of breathing.

In the marine gasteropods there are gills variously situated. The situation of the gills in this order has been taken as a principle of arrangement. Thus, in the Nudibranchiata, the gills are naked and placed upon some part of the back; or, as in the Tritonia, along its entire length.

In the Inferobranchiata, the gills resemble two long rows of leaflets placed on the two sides of the body under a projecting edge formed by the mantle.

In the Tectibranchiata, the gills are on one side of the body only, concealed by a flap derived from the mantle.

In the Pectinibranchiata, the gills are placed internally in a large cavity, into which the water is freely admitted, as in all the spiral univalve sea-shells.

In the Conchiferous Molluscs, which include the oyster, mussel, scallop, cockle, solen, &c., the breathing apparatus is elaborately contrived. The gills are in the form of fringes, sometimes termed in the oyster the beard. Every filament of the branchial fringe, by the help of the microscope, is found to be covered with innumerable cilia, or eyelash-like processes, in constant vibration, thus producing rapid currents in the water, which sweep over the entire surface of the gills, performing the double office of aërating the blood, and carrying towards the mouth the floating animalcules or other nutritious particles which may be spread around.

In the Crustaceous animals, such as the lobster, the crab, and the crayfish, there are fringes and tufts variously disposed, which serves the purpose of gills. In the lobster there are pyramidal tufts, consisting of a central stem covered with vascular filaments, in which blood-vessels ramify.

The Arachnidians, or spiders, are divided into two sections, founded on a difference in their mode of respiration. The Trachearean Arachnidians, to which the mites and itch insects belong, breathe as we shall find insects to breathe, by means of air tubes opening upon the surface of the body, by which the air is conveyed to every part of the system. The Pulmonary Arachnidians, of which the true spiders and the scorpion are examples, breathe by lungs, or pulmonary branchia, as they are termed, as combining in some measure the characters of both lungs and gills; their respiratory organ being a bag containing folded laminæ, on which the air and perhaps sometimes water acts.

In insects, the air is conveyed by means of air tubes and bags opening on the surface of the body, thus at once aërating the blood, and giving to the frame that lightness necessary for flight through the air.

The bee breathes by respiratory bags, of which it has two, opening on the surface of the body by two holes—stigmata, as they are called—and giving rise to several branched tubes. On the other hand, the respiratory apparatus of the grub of this insect, as indeed of most others, is exclusively tubular; and these tubes have a very different distribution from that which they present in the perfect insect. The same is the case with the caterpillar of the silkworm; but even in the perfect animal the respiratory apparatus, in this instance, is tubular alone. Of these tubes one large one runs along each side of the body, and gives off, opposite to each of the numerous openings upon the surface, two sets of branches, one to the lower part of the body, and the other to the upper, in such a manner that the former branches go chiefly to the muscles moving the feet, and the latter to the dorsal blood-vessel and to the several entrails, which in insects are always situated near their back. The stigmata, or orifices of the respiratory tubes, in the caterpillar of this insect, are furnished with a kind of lips, which open or close them at pleasure; and it is probably, by a similar apparatus, that all terrestrial insects regulate the ingress and egress of air employed in respiration. But some terrestrial insects are capable of respiring even under water, and the means by which they do this are extremely curious. In general they carry down with them a considerable portion of air in the interstices of the hairs with which their bodies are covered, and which continually exuding an oily fluid prevents the water from coming in contact with it; they breathe, therefore, under these circumstances, in a kind of natural diving-bell. In some insects however, such as the water scorpion, the air tubes, instead of this contrivance, are provided with long processes extending from the posterior part of the body, the extremities of which, being always above the water, furnish them with a constant supply of fresh air. They are, in fact, a kind of water serpent, or cetaceous animal, in this respect; the bulk of their bodies being under water, while their spiracles, or the holes through which they breathe, are above it. In all insects which fly, it seems to have been the object of nature to carry rather the air to the blood than the blood to the air, and how excellently adapted to this purpose is the tubular and ramified structure of their respiratory apparatus must be sufficiently evident.

In the Myriapoda, such as the multipedes and the centipedes, the air is taken into the body through a series of minute pores or spiracles, placed on each side along the entire length of the animal.

In the Annelida, or red-blooded worms, of which the leech is an example, a series of membranous pouches is provided for respiration, into which narrow ducts open, by which aërated water enters.

In the inferior tribes traces of respiratory organs are still discoverable, though these are so various and so obscure as to render it impossible to comprehend within our limits any particulars of these most rudimentary forms of the function.

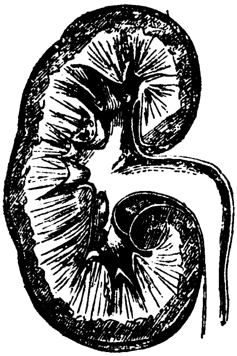
The Kidney.—The urinary organs do not occur in the non-vertebrated animals. They appear for the first time in fishes.

The kidneys are voluminous in fishes. They are composed of microscopic tubuli, which terminate in the larger uriniferous tubes, termed ureters.

In some reptiles the kidneys are lobed, and in the higher species have much the same structure as in birds.

In birds the kidney consists of several distinct lobes, connected by the branches of the ureters; and, in many respects, approach nearer and nearer the character of the kidneys in mammals.

The structure of the kidneys in mammals is somewhat complex: the blood from which the secretion is derived is arterial blood. The kidney consists of two substances; the cortical, or outer surface, and the internal, or medullary. Of these the former is the most vascular, and the latter chiefly composed of uriniferous tubes.' The blood-vessels undergo a peculiar mode of convolution into minute masses, which are termed "Malpighian bodies." The tubules do not communicate directly with the blood-vessels. The secretion, however, first takes place in these tubules, which gradually unite, and finally, under different names, convey the secretion into the canals by which it is transmitted to the bladder.



VERTICAL SECTION OF KIDNEY IN MAN.
Its medullary substance, terminating in uriniferous tubes, opening into the calyx, and passing their secretion into the ureter.

The urinary secretion is plainly of vast importance in the animal economy. When this secretion is interrupted death speedily takes place; and the kind of death which occurs is regarded as a species of poisoning, owing to the blood becoming contaminated with noxious chemical products, which should have been thrown off by the secretion.

Urea and uric acid are the two most remarkable substances known to exist in the urine. Between four and five hundred grains of urea are thrown off by the kidney from the living system in the adult male. The quantity is considerably less in females, in children, and in old people. The quantity of uric acid thrown off in twenty-four hours is much less, being hardly more than one-thirtieth part of the quantity of urea. Both these substances, as before stated, contain a large proportion of nitrogen. They are products of the disintegration of the solids of the body. The saline matters contained in the urine for the most part have a similar source.

Urine contains about seven per cent. of solid matter to ninety-three per cent. of water. Of this solid matter about three per cent. are urea, one-tenth per cent. uric acid, half per cent. phosphates. As the phosphates exist in the solid parts, one source, at least, of these in the urine is the disintegration of the solids of the body. After very violent and long-continued exercise, the urine is observed to contain an unusual abundance of phosphates. There can be no doubt of the general truth of the proposition that the great purpose of the urinary secretion is to convey out of the system certain chemical products, arising from the disintegration of the living parts, though the precise series of chemical changes which take place be not yet fully determined. A general view, then, of this subject is all that is compatible with the plan of this treatise.

We speak currently of the effete matter of the living system being continually thrown off, and that such a separation is essential to the well-being of the body. It is not remarked, however, that merely slightly altered or exhausted portions of the various tissues, such as bone, cartilage, muscle, tendon, nerve, and blood-vessel, are thrown off in those processes by which effete matter is got rid of. It has long been noticed that the fluid contained in those vessels, which have been supposed to perform what is termed interstitial absorption, is homogeneous, and that it never shows signs of having been derived from the disintegration of any such solids as those above enumerated. Hence it was always concluded, in former times, that these absorbent vessels had not only the property of taking up the effete matter at the points where it formed, but that they had also the property of decomposing such effete matters, and of converting them into such a homogeneous fluid as is found in the absorbent vessels. It seems now, however, very doubtful if these absorbent vessels take up anything else but liquids; since it is far more probable that the process by which solid parts are absorbed, consists, first, of a chemical decomposition of the solid, under the influence of the oxygen, conveyed to all parts of the system by the arterial blood, by which it is reduced to a soluble form, and then of its transmission through the coats of the minute veins into the blood. Thus the saline matters, such as the phosphates contained in the portion of solid living substance disintegrated, becomes at once mingled with the blood; while the organic tissues, as consisting of oxygen, hydrogen, carbon, and nitrogen, are converted into water, carbonic acid, urea, and uric acid.

We may judge of the extent to which this conversion goes on from the continual renewal of the blood and the solids of the body, which, while the same weight is retained, cannot take place without a corresponding removal of such parts as, by the progress of development to maturity, have reached the stage of decay and disintegration. The component parts of the living solids plainly undergo changes analogous to the growth, the maturity, the decay and death of the whole body. The new portions of nutriment supplied by the blood, in its successive circulations, correspond, at first, to the embryonic development of a young individual. By degrees these parts advance to maturity, and begin, after a short period of efficient service, to lose the energy of their vitality; so that they are now ready to become the prey of the ordinary chemical affinities of their component elements, and, under the action of the oxygen conveyed by the arterial blood, they become again reduced to matter but one degree removed from the inertness of the dust of the earth.

Of the Sap of Vegetables.—The proper sap of plants undoubtedly corresponds to the blood of animals. By proper sap, however, we are to understand not the ascending but the descending sap—that which, after its ascent from the roots, has undergone an elaboration in the leaves, so as to be prepared to afford to the several tissues a new supply of their proper substance.

The crude or ascending sap is totally different from the elaborated sap. For example, the crude sap of a plant, when flowing upwards in abundance, may afford a refreshing drink, though, after elaboration in the leaves, it may become of a poisonous nature. The *Euphorbia canariensis* is the plant which affords the resin euphorbium of the shops, formerly employed as a blistering substance. This plant the inhabitants of the Canary Islands are said to tap, and draw off the ascending current for the purpose of refreshment, notwithstanding the acrid character of the sap after elaboration.

The descending or elaborated sap abounds in globules, and often, after being withdrawn from the plant, undergoes a species of coagulation. This sap—the proper juice or blood of the plant—plainly contains the materials of the solid parts which compose the structure of the plant, as well as those which enter into its various secretions and excretions.

What, then, is the foundation of the difference between the elaborated, or descending sap, and the ascending or crude sap? In the first place it is evident that crude sap does not contain all the materials which, by a certain transformation, may be converted into the constituents of the perfect sap. Whence, then, are those new materials obtained, which, being added to those of the crude sap, explains the development of the perfect sap? It is plainly the office of the leaves to add those new materials.

It has been a prevalent idea that the leaves of plants correspond to the lungs of animals, and that their use is merely to ventilate or purify the crude sap, as the lungs do the venous blood of animals. A more exact scrutiny of the office of the leaves shows that they are the channel by which a most important part of the food is conveyed into the substance of the plant.

Although carbonic acid is continually given off by certain parts of plants, it is proved, beyond all doubt, that this generation of carbonic acid amounts to but a very small deduction to be made from the far more extensive decomposition of that gas which takes place in the leaves of plants under the influence of light. The carbon derived from this decomposition of carbonic acid becomes fixed in the plant, while free oxygen is given off. Thus the leaves in reality correspond to the digestive organs of animals, since, though nourishment is derived from other sources, yet a most important part enters by this channel; and it even appears that some other parts of the food of plants enters by the leaves, besides the carbon.

The food of plants consists of water, carbonic acid gas, ammonia, and some saline matters; and these several articles of food enter partly by the spongioles of the radicles, and partly by the leaves. The crude or ascending sap is derived from the spongioles of the radicles, and doubtless contains all the saline and earthy matters which enter into the constitution of the plants; it appears, also, to contain portions of the other aliments, particularly the watery part and the ammonia. By the additions made to this sap derived from the spongioles, the sap becomes matured, and prepared for the general nutrition of the tissues, and the supply of the secretions. It comes now to contain fecula, gum, sugar, lignin, and also the proteine compounds, albumen, fibrine, caseine, &c.; or substances readily convertible into these, by which the annual additions to the stem is made, the fruit is developed, and the several peculiar secretions, such as oil, fixed or volatile, resin, gum-resin, balsam, camphor, and the like, are supplied. And after the sap has served these uses, there is a surplus of nutritive matter left, which is laid up for the supply of the wants of the vegetable economy in the subsequent year; for, obscure as this subject still is, it seems certain that the sap which first rises from the soil in spring becomes mingled with organic products formed in the previous year, by the aid of which, before the leaves have commenced their office, various important effects in the vegetable economy are accomplished; and this in accordance with a rule of organic nature already referred to, namely, that for materials from without to become fit to be incorporated with pre-existing organic tissues, a mixture with the products of living action is a usual preliminary.

The respiration of plants, like the respiration of animals, consists in the evolution of carbonic acid, and the consequent development of temperature. By this evolution of carbon, which appears to take place at all times, though in minute proportion, some purification of the proper sap must be effected; and there also appears to be other means of excretion, by which the same end is still further promoted.

Of Reproduction.—The continual renovation of the tissues composing the frame of an adult animal, and of the leaves of trees in each successive spring, bears a striking analogy to the reproduction of species by the individual, whether animal or plant.

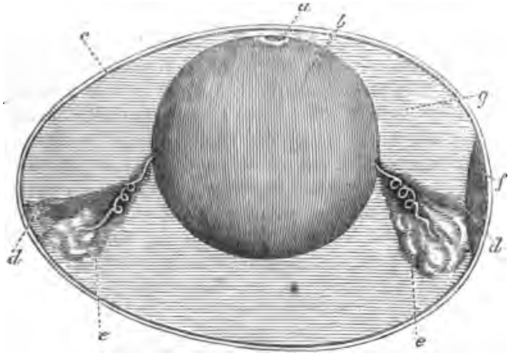
A germ separates from the body of the parent, which, under the application of certain conditions, different in different divisions of organic nature, becomes developed into a new individual.

The whole process is of the most wonderful character from beginning to end, and in whatever part of organic nature it is studied. The least complicated mode of reproduction is found in such organisms as the red snow (*protococcus nivalis*), which consists of a simple aggregation of vesicles, without any definite arrangement,—sometimes united, but capable of existing separately. In simple organisms of this kind, simple rupture gives independent existence to the rudiments of new individuals contained within them.

The successive development of the several structures belonging to the mature individual in the higher parts of both kingdoms, is not less wonderful than the varied primitive development of the germs.

The progress of the development of the chick during incubation affords one of the most interesting examples of this ulterior stage of reproduction.

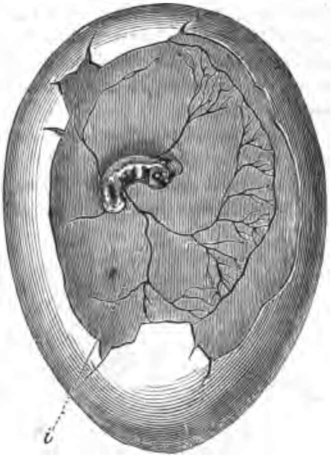
Let us briefly review the anatomy of the egg at the commencement of incubation. Beneath the shell there is a membrane consisting of two layers, which, by their separation at the larger end, form a space filled with air, especially rich in oxygen, this air vesicle being destined to serve for respiration. Within the inner layer of this membrane lies the white, and within the white, enclosed in its proper membrane, the yolk. From each extremity of the yolk-bag proceeds into the white a knotty body, terminating in a flocculent extremity. These two bodies are termed the *chalazæ*, and their effect is to keep the yolk uppermost in the white; for by shaking an egg violently, the connexion of these with the white is destroyed, the yolk sinking to whatever end of the shell is downwards; and this is the secret of making an egg stand upon end, without proceeding to the violent expedient reported to have been employed by Columbus. On the surface of the yolk-bag is a small round milk-white spot, called the cicatricula, surrounded by one or more whitish concentric circles. The cicatricula is the blastoderm, or germinal membrane, from which the future being is developed. Beneath the germinal membrane there is a canal, which leads to a chamber in the centre of the yolk, and which is filled with a whitish granular substance. Such is the description of the egg in the fowl, and in its general character it represents the matured ovum in vertebrate animals.



SECTION OF A BIRD'S EGG.
a, cicatricula; *b*, yolk-bag; *c*, membrane lining the shell; *d*, attachment of chalazæ; *f*, air space; *g*, albumen.

As soon as incubation commences, the germinal membrane becomes distinctly separate from the yolk and yolk-bag, spreading and assuming the form of a central pellucid spot, surrounded by a broad dark ring. At the same time it becomes thickened and prominent, and is soon separable into three layers; of these the exterior is a serous layer, the internal a mucous layer, and between the two is situated a vascular layer in which vessels soon become apparent. From the first, all the serous structures of the future animal are developed, as from the mucous layer are all the mucous structures, and from the middle all the vascular structures.

Towards the close of the first day, the serous or outer layer has become thickened into the first rudiment of the dorsal portion of the future embryo, while the two other layers still remain unaltered. At the commencement of the second day, the anterior portion of the embryo is dilated, and the three membranes which represent it have become bent down. At the conclusion of the second day, this inflection is carried still farther, and in the vascular layer a beating point, the *punctum saliens*, the first appearance of a heart, has become developed. On the third day, the serous membrane has become reflected over the back of the fœtus; at one extremity investing the head with a serous covering, and at the other extremity investing the tail. This reflection of the serous membrane is finally to form the amnion or inner lining of the bag in which the fœtus is to be contained.

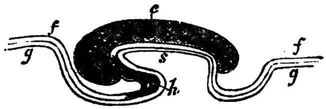


EMBRYO OF BIRD.
With the vessels (*i*) of the vascular area, after four days' incubation.

The mucous layer, or that next the yolk, at this time lines the open space which is to form the abdominal cavity, and by its inflections gives origin to the rudiments of the abdominal viscera.

The heart in the vascular layer is now seen to be composed of two chambers; and further, the branchial arteries are discovered which join to form the aorta.

On the fifth day, the outlines of the viscera are tolerably distinct, the sac of the amnion is completed, and the liver and lungs begin to appear; the bag of the altantois is well developed. The heart is still that of a fish, and the aorta formed by the branchial arches, which had been visible from the third day. The successive changes which take place on the vascular system are rather complex. Thus, of five pairs of vascular branchial arches, which at first by their union formed the aorta, as in fishes, those of the first pair on both sides, and of the fifth on the left side, speedily disappear. The third on each side becomes the brachio-cephalic trunks; the fourth of the right side becomes the descending aorta; while the fifth of the right side, and the fourth of the left side, are converted into the pulmonary arteries. The very short trunk common to the two pulmonary arteries, and also the equally short trunk of the aorta, are produced by the transformation of the single cavity of the original "bulbus arterosus" into two distinct canals; and thus this wonderful metamorphosis is completed.—*The General Structure of the Animal Kingdom*, by Jones, p. 627.

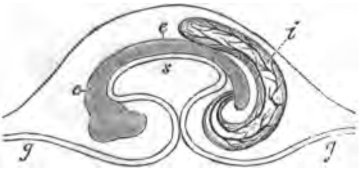


e, Formation of the digestive cavity; *c*, embryo; *f*, layers of germinal membrane; *h*, heart; *s*, stomach.

About five days from the commencement of incubation, the vascular layer of the germinal membrane has spread extensively over the yolk; and as the vessels are formed, they are found to converge towards the navel of the embryo, and to constitute a distinct system of arteries and veins communicating with the aorta and the heart of the fœtus, and forming a vascular circle surrounding the yolk. These vessels are termed omphalo-mesenteric vessels. The omphalo-mesenteric arteries arise from the mesenteric arteries, and the omphalo-mesenteric veins return to the vena cava of the chick.

When the intestinal system has reached some degree of development, a communication is found to have arisen between the yolk and the intestine, by a wide duct termed the vitello-intestinal duct, and by which the nutritive substance of the yolk enters the alimentary canal for the alimentation of the embryo. By the time incubation is completed, the yolk-bag is empty, and the place of the duct is marked merely by a little cæcal appendage.

The allantoid membrane first makes its appearance in the early part of incubation, while the abdomen is still open, as a delicate bag derived from the anterior part of the rectum; but it quickly enlarges, so as at last to line nearly the whole extent of the membrane of the shell; and being thus exposed to the air, which penetrates the shell, it becomes an important organ of respiration. When fully developed, it is copiously supplied with arteries and veins. The arteries derived from the common iliac trunks correspond to the umbilical arteries in mammals, and the veins corresponding to the umbilical veins, reach the inferior vena cava.



FORMATION OF THE ALLANTOIS.
c, *e*, embryo; *g*, layers of germinal membrane; *s*, stomach; *i*, allantois.

About the nineteenth day of incubation, the air-vessel at the large extremity of the egg is ruptured, the lungs begin to breathe the air which it contained, and the vessels of the allantois become by degrees obliterated. On the twenty-first day the chick escapes from the shell, to begin a new phase of life.

On the fourth day the chick is about four lines in length; on the sixth day it is seven lines; and then what appear to be voluntary motions are first observed. Ossification commences on the ninth day, and on the fourteenth day the feathers appear; and if taken out of the egg, the chick can open its mouth.

Reproduction in the Vegetable Kingdom.—The first stage of reproduction in the vegetable kingdom is the maturation of the seed; the second stage the germination of the seed, by which a new living plant is produced.

The seed is matured, as a general rule, within the inferior portion of the pistil or female organ, termed sometimes germen, sometimes ovary—the latter term being most used. This inferior portion of the pistil becomes, by maturation, the fruit or seed-vessel, called also the pericarp. Familiar examples of the pericarp are the cherry, the apple, the pear, the poppy-head, the flat pouches of garden honesty, and of shepherd's purse, the French bean, and the pea-pod.

If we examine the several flowers in which these pericarps form, we shall find all of them are mere enlargements of the base of the pistil—that is, of the germen or ovary.

If the interior of the germen or ovary be examined at an early period, the rudiments of the seeds are found to be already present in the form of minute membranes not yet closed in on every side. The condition requisite for the perfect development of these rudimentary parts into perfect seeds is the entrance into their interior of a pollen granule derived from the male organ or stamen. The upper part of the stamen, named anther, secretes the pollen, which, being transferred to the upper part of the pistil, there finds entrance, and descends through the middle part or stile into the cavity of the germen or ovary, and finally into the cavity of the rudiment of the seed. Forthwith the seed becomes developed into a perfect part.

The perfect seed contains, beneath its exterior membranes, a part destined to be developed into the stem, another part destined to be developed into the root, and other parts destined to supply nourishment up to the period when the new individual has attained sufficient development to draw the means of support from the soil and from the atmosphere. The nourishment contained in the substance of seeds is starch.

The conditions necessary for the development of a seed into a new plant are the presence of moisture, warmth, and atmospheric air. When put into the earth, not far from the surface, the seed swells by the agency of moisture, and imbibes oxygen from the air diffused through the water of the soil. In proportion as it acquires oxygen, it throws off carbonic acid. The starch during this process is, in part at least, changed to sugar, or to a soluble substance more readily conveyed onwards, as the stem and radicle are developed. Besides starch, the seed contains certain saline bodies, such as phosphates, and the other mineral constituents found in organic bodies, which serve for a supply till the root is sufficiently developed to draw such constituents from the soil.

Under the influences of these sources of supply, the gemmule, or part of the seed representing the stem, at last arises above the ground, and the radicle, or part representing the root, descends into the earth. The parts of the seed destined to supply nourishment are the seed lobes, or cotyledonary bodies, and the albumen; the latter being present only in certain orders of seeds. When the albumen is absent, the cotyledonary bodies are proportionally larger. In many plants these seed-lobes, or cotyledonary bodies, rise above ground in the form of temporary leaves, and plainly perform for a time the office of leaves, by drawing nourishment from the atmosphere. But as the proper leaves form on the stem, the cotyledonary bodies, whether they ascend into the atmosphere or remain below ground, shrivel and decay; and the same thing happens to the albumen when it is present.

When this stage is attained, the growth of the new individual proceeds on much the same plan as in mature plants.

Recapitulation.—Such, then, is an outline of organic life in the two great departments of nature endowed with vitality; and a brief review of the connexions of these two kingdoms of nature with each other, and of their common dependence on mineral nature, will form a proper conclusion to this section of our treatise.

We have seen that the elements which compose the animal kingdom exist in the mineral kingdom. The original position of these elements is in the rocks composing the crust of the earth, and in the water which rests on its surface, or in its gaseous envelope, the atmosphere. The next position in which these elements are found, previously to their becoming part of the substance of the bodies of animals, is in the component parts of the vegetable kingdom—namely, in parts of vegetables which serve for food to animals, such as the roots of the potato, the turnip, the carrot, the parsnip, the onion, the leek, the beet, the leaves of the various species of brassica, spinach, parsley, lettuce, the seeds of wheat, barley, oats, and Indian corn, rice, and the like. We next find these elements advanced to the rank of constituents of an animal body, and sometimes passing from one animal body to another. The next transition of these elements is a return to the mineral state; not, indeed, for the most part to resume their original form, if that were the component parts of a rock, but to enter into the soil, or to join the waters of the surface, or to float in the air till received again into the vegetable kingdom, to perform the same round as before.

For example, one of the ores of manganese, which when exposed to heat gives off oxygen abundantly, occurs in the oldest strata of the crust of the earth. Thus, an atom of oxygen which has lain fixed in a rock for an incalculable number of ages, may have been set free only a year or two ago, and yet if the history of its progress could be traced, it would fill a volume.

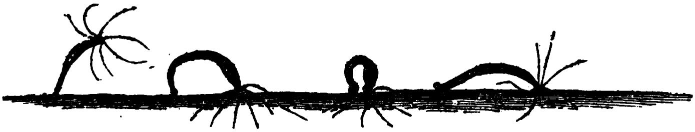
Its first condition, after being set free from its imprisonment, is a particle freely floating in the atmosphere. We may suppose, then, that it descends to the earth absorbed in a drop of rain. It unites with a minute portion of carbon existing in the soil, to form carbonic acid, which, being taken up by the root of some useless weed, is conveyed to a leaf, and then again set free,—its companion, the carbon, being retained. We may next suppose that amid a thunder-storm, as it floats high in the air, it is yoked to an atom of hydrogen, to form an atom of water, and that it again descends to the earth; now not as an impregnation but as a minute integral portion of a drop of rain. It is again taken up, we will suppose, by the radicle of such a grass as the common poa or meadow grass, and the atom of water being decomposed, it becomes fixed in a minute portion of albumen within the leaf of the grass. By-and-by this grass is cropped by a cow grazing in the pasture; and the albumen being soon changed to caseine, it comes forth as a constituent of milk. It is quickly found in a human stomach undergoing the process of digestion, and being received into the blood circulates there, to escape, perhaps, from its new possessor by a cut of the finger.

The blood left exposed to the air quickly putrefies, and our atom of oxygen escapes from the fibrine or albumen in which it existed, in company again with carbon, or in the form of carbonic acid. It probably soon comes into contact with a leaf, for example a spinach leaf, and the carbon being disjoined from it and fixed in the plant, our atom again becomes free. It now, for the first time, becomes the victim of respiration, being drawn into the lungs of a passer-by. Being conveyed over his body with the arterial blood, after passing through his heart, it is quickly found uniting with the debris of the muscular fibres which have been longest in action; and, returning in the venous blood to the lung, united with a portion of carbon, is thrown out as a part of the expired air, in the shape of carbonic acid. It is now carried high into the air, and falling into the southward current, is quickly found journeying westward, with the trade-wind, at a lower level and in a warmer region. As it reaches the luxuriant vegetation of a West Indian Island, it is speedily disjoined from its associated carbon, and again set free, leaving its companion to form part of the substance of a luxuriant banana. Soaring again in the air, it forms part of the northern current, and in no long time is again found fit to assist the respiration of the inhabitants of the same region from which a short time before it had departed in company with a particle of carbon.

Such is a slight specimen of the unceasing changes which the particles composing organic nature undergo. There is a circulation of particles from the mineral kingdom through the vegetable to the animal kingdom; and the air which the animal kingdom contaminates the vegetable kingdom purifies. Lastly, the surplus of contaminated air, which the limited vegetation of temperate countries cannot purify, is wafted to feel the influence of a tropical vegetation, and brought back restored to the required state of purity for animal existence.

With the following passage from Liebig, one of the greatest names in organic chemistry, we shall close our account of the vegetative functions:—"When the vegetable kingdom, in the temperate and cold zones, ceases to decompose the carbonic acid generated by the processes of respiration and combustion, the proper, constant, and inexhaustible sources of oxygen gas are the tropics and warm climates, where a sky, seldom clouded, permits the glowing rays of the sun to shine upon an immeasurably luxuriant vegetation. In our winter, when artificial warmth must replace deficient heat of the sun, carbonic acid is produced in superabundance, and is expended in the nourishment of tropical plants. The great stream of air which is occasioned by the heating of the equatorial regions, and by the revolution of the earth, carries with it, in its passage to the equator, the carbonic acid generated during our winters; and in its return to the polar regions brings with it the oxygen produced by the tropical vegetation."

The Locomotion of Animals.—The next subject for our consideration is that function by which living beings are enabled to move from place to place. Among the lowest orders of animal existences, as in some zoophytes and mollusca, we find those which are permanently stationary, and, like plants, unable to leave the substance to which they are attached. And even some of these who do move about, as the sea-blubber, the sea-pen, and many others, do so passively; and, like the duckweed and star-grass among plants, are moved in water chiefly by the currents, and tides, and winds; but the number of those in whom locomotion is otherwise than active, is certainly very small. Again, during one period of their existence, the fixed zoophytes do possess a power of locomotion. Thus the young sponge, after its separation from the parent stem, for several days swims about as if to find the appropriate spot to which it may attach itself; while the cilia, or arm-like appendages, to the action of which its locomotive powers are due, fade and disappear, as if no longer required, after the animal has attached itself to the rock. Similar properties are found among the polypes lodged in the madrepores and corals, with which all are familiar. In the hydra, a species of polype inhabiting our fresh waters, for the knowledge of which we are indebted to M. Trembley, of Geneva, we find an early example of locomotive powers curious in the extreme. If the animal is introduced into a glass, it may be seen, as in the figure, when standing erect slowly to bend its body, until its mouth touches the surface of the vessel; its foot is then detached, and brought towards the head, which is then projected forwards, and the process repeated, until a desirable position is obtained. We will pass over the Infusoria, so named by being to be found in all animal or vegetable infusions, after being kept a sufficient time; since they are all microscopic, and not to be seen by the naked eye. Their movements are very rapid; and the microscope reveals, as is familiar to most persons, a strange and busily moving mob even in a drop of water. Among the Medusæ some are remarkable for their organs of locomotion, being furnished with an apparatus not unlike the fins of a fish,



LOCOMOTION OF HYDRA VIRIDIS—*after Trembley.*

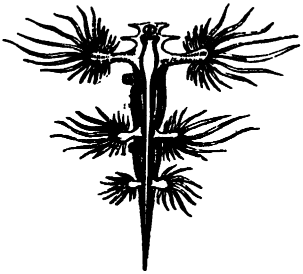
with which they strike the water vertically, and give an ascending impulse to their bodies. Among the molluscs, the motions of the snail are familiar to every one. They are effected by what is called its foot, or a mass of muscular fibre, situated on the strong membrane which contains the entrails, and also attached to the shell. It glides along the surface, partly by forming a vacuum by means of this organ, and partly by a viscid mucillage secreted by the part. It is thus, also, that some bivalve molluscs, as the common cockle, mussels, razor shell-fish, and others, progress—the animal protruding its foot beyond the shell, and crawling along upon it; and it is furnished also with the same kind of adhesive mucilage, for the purpose not only of steadying its steps during motion, but also, as drawn out into threads under the name of byssus, of preventing it, when at rest, from being washed away, by tides and currents, from the rocks to which it attaches itself.

Advancing in this great class, we find some animals, as the cuttle, moving by a kind of arms or tentacula attached to their head, and employed as oars, or as feet, when moving along the bottom of the sea. On account of the singular place of attachment of the feet, the animals of this, the highest order of molluscs are called Cephalopods (Gr. *kephale*, head, and *pous*, foot). With the exception of the pearly nautilus (*Nautilus pompilius*), which has many tentacular organs attached to the head, all other cephalopods have eight arms; to which, in some kinds, as, *e. g.*, the calamary and sepia, two long and slender tentacula are added, which can be retracted into sheaths. Both the eight ordinary arms and the two tentacles are provided with suckers, by which the animal can attach itself at pleasure. The paper nautilus (*Argonauta*), has but eight feet, and one pair of these expand at their extremities into broad and thin membranes; the fabled use of which has afforded a beautiful subject for poetic imagery in all ages; but similar appendages occur in *Octopus violaceus*, and in *Octopus velifer*, in which both the first and second pairs of feet support broad and thin membranes at their extremities. Now, neither of these species inhabit a shell in which the expanded membranes could be used to waft the animal along the surface of the ocean, as has been said or sung of the Argonaut, from Aristotle to Cuvier, and from Callimachus to Byron.

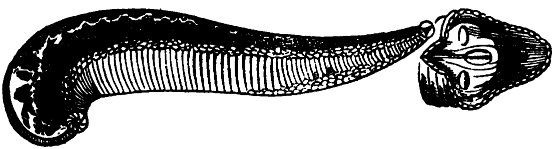
The comparative anatomist, who has devoted most attention to the structure and economy of the class of Cephalopods, has concluded that—"the physiologist, in contemplating the structure of the velated arms, is compelled to deny them the power of being maintained erect and expanded to meet the breeze. What their real function may be is still to be determined; but the removal of the erroneous impressions entertained on the subject is the first step towards the attainment of truth."* Since the article from which the above passage is quoted was published, it has been shown that the membranous arms of the argonaut are the organs for secreting and repairing the shell. This function of the supposed sails of the paper nautilus has been determined by the experiments, instituted, at the suggestion of Professor Owen, by Madame Power, at Messina in Sicily. One of the "sails" was cut off in several living specimens; the right sail being removed in some, the left in others; and the creatures were then kept in a sub-marine cage, and supplied with food. Some of them survived the operation four months, when it was found that the shell had grown only on that side on which the membranous arm had been preserved. By these and other observations it has been finally determined, not only that the argonaut is the veritable constructor of the beautiful and delicate shell which it inhabits; but that its expanded membrenous arms never act as sails

* See Professor Owen's Article, "Cephalopoda," Cyclopædia of Anat. and Physiol., vol. i. (1836), p. 527.

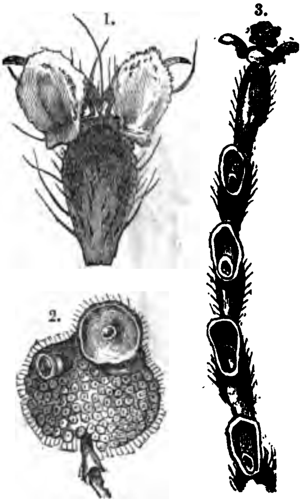
to catch the wind. While the Glaucus, a beautiful little mollusc, of the Indian Seas and Mediterranean, painted in blue and silver, swims with great swiftness by its conical and oar-like appendages.


GLAUCUS FOSTERI.

Passing now to the Annelidæ, we find the earthworm progressing by means of setæ, or bristles, attached to the skin, which the animal fixes on the ground, while, by the elongation of the rings which encircle the body, it moves onwards. Then the head is applied and fixed to the ground, and the body, by the contraction of its rings, drawn towards it. In the Nereis we find numerous tentacula as organs of locomotion, by which, and by undulating inflexions of the body, the animal swims with great rapidity: while the leech, independently of its power of swimming by ordinary vermiform motion, is furnished with an apparatus for suction at either extremity of its body. By fixing, alternately, one or the other, and drawing its body towards it the animal advances at pleasure.


THE LEECH (HIRUDO OFFICINALIS.)

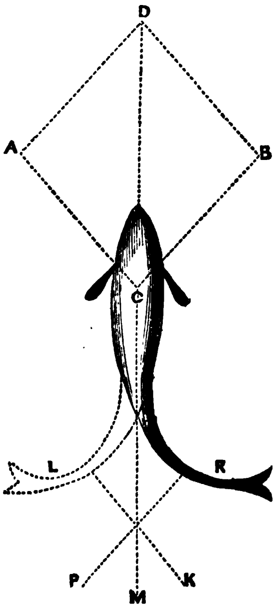
The motion of insects is much more perfect than that of any of the preceding classes, while a calcareous or horny covering gives attachment to muscles of great power, and enables individuals to move with immense force and velocity. All spiders dart upon their prey with great rapidity, while some species possess the power of conveying themselves to considerable distances by means of threads, which, propelled from their bodies, they cling to, and are wafted upon them by the winds. The crabs move with great rapidity on the ground; but, from the construction of their joints, they can only progress sideways. The lobsters and cray-fish, again, are only adapted for swimming; but the muscles of both are highly organised and powerful. All winged insects have six legs; and many moreover have, either in the course of their legs, or at their extremities, numerous suckers, by which they form a vacuum every time their legs come in contact with any surface. It is in this way that flies crawl upon a perpendicular surface, or on a smooth mirror, or walk along the ceiling of a room. The structure of these suckers is very beautiful, and is best seen in the common blue-bottle fly (*Musca vomi-*



1. Suckers of Blue-bottle Fly.
2. " Great Water Beetle.
3. " Yellow Saw Fly.

taria), the great water beetle (*Ditiscus marginalis*), and the yellow saw-fly (*Cimex Lutta*). But the most remarkable organs of locomotion in insects are their wings. Of these, however, it is sufficient here to say, that they are moved by muscles of immense powers, and that the velocity with which they are moved is at least as remarkable as the force.

Fishes.—We next come to Fishes, most of whom effect locomotion by their fins, and of these they employ chiefly the pectoral and ventral pairs, which are strictly analogous to the upper and lower extremities of the superior tribes of animals. Some fishes effect their progression by the motion not of the fins but of the spine; as the lamprey, which has neither pectoral nor ventral fins, and which seems to move in its natural element, the mud, entirely by the lateral flexion of its spine, which it first draws into an S-like curve, and then shoots forward the anterior portion. The same is the case, also, with the eel, when it creeps on land. Others again, as most flat fishes, which, like the lamprey, have neither pectoral nor ventral fins, use their tails principally in making progress in the water. This operation is extremely simple. Everybody knows that the ordinary way of propelling forwards a boat is by rowing; that is to say, by means of one or more pairs of oars passed over its sides, the action of which is exactly similar to the pectoral fins of fishes. But it is likewise well known that a boat may be, with equal certainty, urged forwards by what is called sculling; that is to say, by means of one oar passed over its stern, and continually moved in the water from side to side. Now, it is precisely upon this latter principle that the tail of fishes, moving from side to side, operates in propelling them forward. It is evident that the oar on the one hand, and the tail on the other, in this alternate lateral motion, is continually displacing a quantity of water great in proportion to the length of the instrument employed, and consequently to the sweep which it makes in its oscillation; and it is by the resistance which the water makes to this displacement, by the oar or tail, in coming from its extreme sweep to the axis or mesial plane of the boat or fish, that either is urged onwards. "Let us suppose," says Dr. Roget, "that the tail is slightly inclined to the right, as shown in the annexed figure. If in this situation the muscles of the left side, tending to bring the tail in a right line with the body, are suddenly thrown into action, the resistance of the water, by re-acting against the broad surface of the tail in the direction P R perpendicular to the surface, will cause the muscular action to give the whole body an impulse in that direction, and the centre of gravity, C, will move onwards in the direction C B, parallel to P R. This impulse is not destroyed by the further flexion of the tail towards the left side, because the principal force, executed by the muscles, has already been expended in the motion from R to M, in bringing it to a straight line with the body; and the force which carries it on to L is much weaker, and therefore



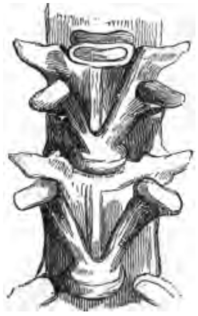
MOTION OF FISHES.

occasions a more feeble re-action. When the tail has arrived at the position L, indicated by the dotted outline, a similar action of the muscles on the right side will create a resistance, and an impulse in the direction of K L, and a motion of the whole body in the same direction, C A. These impulses being repeated in quick succession, the fish moves forwards in the diagonal, C D, intermediate between the directions of the two forces."

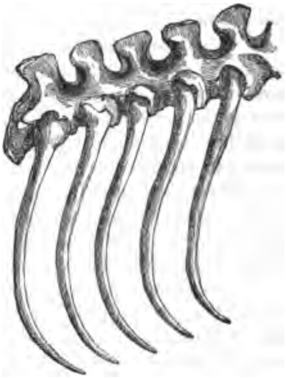
It should be added to this description, however, that fishes in general have the power of "feathering" their tails—that is to say, of so puckering up the lobes in their outward motion, as to make them displace as little water as possible—since the effect of the resistance of the water in this direction must obviously be that of retarding their course; while, on the other hand, they expand these lobes on their return to the mesial line, in order that they may displace as much water as possible; since it is upon the re-action of the water in this direction that they rely for their advancement.

The bodies of fishes are of very nearly the same specific gravity as the water in which they live, owing to the great quantity of fat which most of them contain; so that very little effort is required to keep them at any given height, and their descent or ascent in the water is comparatively easy; the latter being further promoted by the faculty they possess of filling their air-bladder at pleasure with air. When they attach themselves to rocks, it is by means of suckers, as in other tribes; and when they leap from the surface of the water, it is by a sudden and forcible extension of their bodies after a strong flexion,—the elasticity of the water thus giving them the force of a projectile. Some fishes also, as the flying kinds, are capable of using their long fins in the air almost in the manner of the wings of birds—a hundred yards being no unusual flight.

Reptiles.—In serpents we find the spine as an organ of locomotion; and these, unlike all other vertebrata, have only abdominal and caudal vertebræ, the motions of which are exceedingly free upon each other. Serpents differ from fishes, in the circumstance of their spine supporting their true ribs, as well as in that of the bodies of their vertebræ being attached to each other, not by means of an interposed fluid, contained in a shut cavity formed by the juxtaposition of the bones, but by means of a rounded head on the posterior part of the body of each, which is received into a corresponding socket on the anterior part of the one behind it. The spinous processes, also, of the vertebræ of serpents being in general considerably shorter than those of most fishes, the motions of their spinal column are not only lateral, but in a great measure upwards and downwards also; although some painters and statuaries appear to have a little overdone this matter, and to have represented flexures of the bodies of serpents where no countenance can be given to them by anatomy. There are limits, in this respect, beyond which we cannot allow even the sublime hand of the sculptor of the Laocoon to pass without reproach. But although the motions of serpents are thus very similar to those of "the wandering eel" in its peregrinations on the grass, the former has an assistance which the latter has not, and one which appears to constitute a link in the transition of the spine, as an organ of locomotion, very similar to that constituted by the bristles of the aphrodita, or sea-mouse, in the same transition in the invertebrate. This assistance is the ribs, which in serpents are, in fact, organs, not so much of respiration—as is the case in most lizards, in birds, and in mammiferous

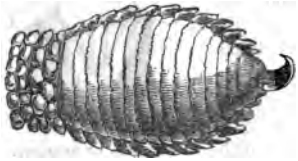

VERTEBRA OF SERPENT.

animals—as of progression; and the raising or drawing forward of these ribs corresponds more to advancing a leg than to any other motion of animals furnished with proper limbs. Not only, then, is the spinal column of serpents a means of helping them forwards, but the ribs being at the same time drawn towards their head, the transverse plates on the lower surface of the body, with which they are connected, move forward, as it were, like so many feet, when the spine and the rest of the body are drawn forwards upon them. It is thus that the serpent fulfils the curse pronounced upon the first tempter, "Upon thy belly shalt thou go, all the days of thy life." It is the only "beast of the field"—in other words, the only terrestrial vertebrated animal—which does not employ legs as an organ of progression; but the transition, in this respect, from the serpent to those vertebrated animals in which these organs are both structurally and functionally most developed, is extremely insidious, and furnish another striking illustration of the axiom, that nature never advances by sudden leaps in her productions, and that she knows no chasms in the chain of creation. She has given even to the serpent a kind of rudimentary legs, or, at least, arms, manifesting themselves in a kind of claws, situated in most species under the common covering of the body, but in some few projecting a little beyond it; and in some kinds of lizards—the snake-lizard, for example—the improvement in this respect is hardly appreciable. The legs of this animal are scarcely less rudimentary than those of the serpents; and, like the caterpillar among the invertebrate tribes, it probably advances, at least equally, by means of its spine, as by means of its legs. A further step is gained in the case of the land salamander, which, like the centipede, uses its legs—which are considerably more developed than in the snake-lizard—more than its spine as an organ of locomotion; but its legs are still almost as often tilted up into the air as resting on the ground, in the process of walking, and it is not until we come to some of the higher tribes of lizards—as to those of insects in general—that we find the legs exclusively and unequivocally employed as instruments of progression.



RIBS OF SERPENT.

Some lizards, also, move up perpendicular surfaces by a species of suction; the soles of their feet, as in the gecko, being provided with a series of soft plates, which, being drawn up at pleasure, produce the requisite vacuum. Other reptiles—as the tortoise—make progress on land by crawling, and the frog by crawling and leaping; others—as the flying-lizard—use their ribs, not, like serpents, as legs, but as wings. In the water most reptiles use their legs as fishes do their fins; and some of them, as turtles, keep themselves afloat by a collection of air beneath their dorsal shield.



SUCKER OF LACERTA GECKO.

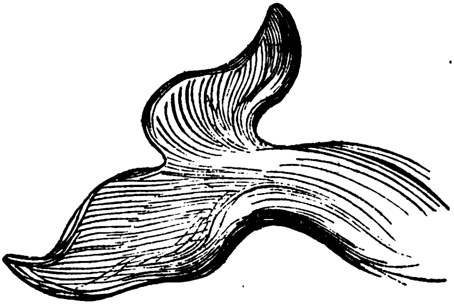
Birds.—When on land, the progression of birds is effected by either walking or hopping on their posterior extremities only, birds being the only proper bipeds among the lower animals; and they are enabled to keep themselves erect without effort, since their centre of gravity corresponds to the region where the anterior extremities are attached, owing, in most birds, to the legs being directed forwards, and the toes more elongated; but in some—as the penguin and the puffin—to the trunk of the body being placed almost vertically. Birds are enabled to float in the water, owing to their specific gravity being in general less than that of this fluid, and hence they displace only as much of it as is equal to their own weight, according to the well-known hydrostatic law; and they move along its surface by the action of webbed feet, the swan appearing to use its wings, in addition, almost in the manner of sails. But the characteristic organ of locomotion in birds is their wings, corresponding, in their more essential parts, as well with the pectoral fins of fishes as with the forelegs of reptiles and quadrupeds, and the arms of man. The motions of these are effected by a mass of muscles, weighing more than all the rest of the muscular system of the animal, and arising from a breast-bone of a larger size than is met with in any other class of animals; the immense power thus acquired being no more than is necessary to enable them at once to support themselves in the air, and to move through it with astonishing velocity. The former they effect by continually renewing the column of air below them—and which must be displaced, in order to allow of their falling to the ground—more rapidly than this displacement can take place; and the latter, by using their wings in the manner of oars, while the tail, at the same time, serves them as a rudder. In this way birds are known to have travelled at the rate of sixty, or even one hundred, miles an hour.

PENGUIN.

Mammals.—To the motion of fishes in the water an air-bladder is essential; but in the cetaceous tribes this organ, as one of locomotion, is superseded; since, when they desire to rise in the water, all they have to do is to strike a few smart blows with the tail downwards, when their heads are naturally carried in an opposite direction, and when they wish to sink, a few similar strokes with the tail in the upward direction at once serve to bury their heads beneath the water. A reference to the diagram (page 90), when viewed sideways, will at once give the explanation of this simple fact.

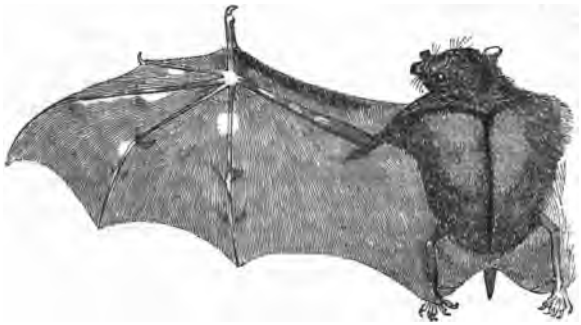
The tail, being the chief organ of locomotion among cetaceous animals, is a most powerful instrument; and accordingly, a ship's boat, when struck by the tail of the whale, may be divided, as by an axe, or buried beneath the waters.

The downward and upward motion of the tail of the cetaceous animals in swimming (attended, as it must be, with a corresponding rising and sinking of the

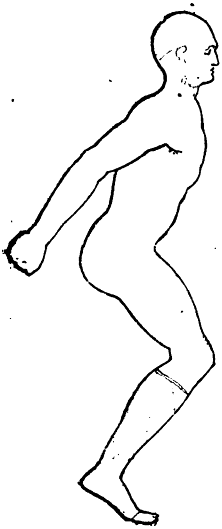


TAIL OF THE WHALE.

head as it advances) gives to many of them, as they sport near the surface of the water, the appearance of revolving like a wheel, and has led to very false impressions respecting the form of their bodies. The dolphin, accordingly, is always represented in ancient statues and bas-reliefs as a being with a rounded head and arched back; and there are few who see the animal for the first time that can reconcile the slim and tapering creature before them with the blunt-headed, round-shouldered figure with which their fancy has associated it. Generally speaking, the muscles which move the tail downwards in the cetaceous tribes, are stronger than those which raise it; and this is so much the case with the white dolphin, that, according to Pallas, it is accustomed to bend its tail under its body in swimming, almost like that of a boiled lobster; but it is obvious that if the tail be held for an instant stationary in this position, while the body is advancing, the effect will be to depress the head, for the same reason that the continued inclination of the tail of fishes to the right side serves to turn the animal in this direction. During the whole sweep, however, that the tail is making downwards, the head must incline upwards; and this appears to be another means, in addition to their little specific gravity, by which these animals are enabled, with very little effort, to keep the top of their heads above the water. Their total immersion in this fluid is always prejudicial to them; and nature has therefore rendered it a forced state, not only by opposing difficulties to their descent, but by making their muscular motion to co-operate with their lightness in bringing them again to the surface.


HARPYIA PALLASII.

Very few quadrupeds are capable of moving through the air—the bat, the flying squirrel, and some species of lemur being among these,—and this they effect, not like the flying fishes and birds, alone by their anterior extremities, nor, like the flying lizards, by their ribs, but by wing-like membranes extended between their anterior and posterior extremities, the motions of both of which are requisite to call them into action. Quadrupeds in general use their upper limbs only in conjunction with their lower in the act of progression; but some few, as squirrels and apes, use them also as we do our arms, the arrangement of their skeleton being expressly adapted for the purpose. In standing, they use in general all the four legs; and as the centre of gravity is thus preserved without effort, they easily sleep in this posture. Some few, however, as the kangaroo and jerboa, rest on their hinder legs alone, the centre of gravity falling in them almost perpendicularly; but such also use their strong tails, like another leg, to steady them. In climbing, some, like the walrus or the lizard, seem to attach themselves to any surface, by forming a vacuum with the soles of their feet; but the majority use their claws for this purpose, and these in some tribes, as the sloths and ant-eaters, are so long, that they are almost incapable of walking on a horizontal plane. Their manner of performing the trot, gallop, and amble, we shall not stop to describe, but conclude this section of our work with a few remarks on



Leaping.—The leaping of terrestrial animals, from man down to the flea, consists of a sudden and forcible extension of the limbs, after flexion, from a medium which offers more or less resistance. The length of the body is thus suddenly increased; and as it presses on any unyielding medium, it is re-acted upon with a force equal to that with which it presses, and an impulse is accordingly thrown into it, sufficient to detach it, and project it to a greater or less distance. But while the process is of course very much facilitated by the fulcrum being firm and elastic—a fact well known to opera-dancers and vaulters by profession, who commonly use spring-boards to assist them in their bounds—it cannot be effected by terrestrial animals from the water, nor even from soft, boggy ground, unless their bodies be very light, or their feet very broad, because the points by which they in general press upon their fulcrum, compared with the weight of their whole body, namely, the extremity of their legs, are so small as to be resisted only by the very narrow columns of this fulcrum, which therefore, instead of re-acting upon them, immediately give way to the pressure which they sustain. Such, however, is not the case with fishes, the broad flat part of the tail of which, or, if the tail be tapering, at least the broad flat part of the body which leads to the tail, is brought directly to bear upon the water; so that a very considerable column of resistance, in proportion to the whole bulk and weight of the animal, is called into re-action. Nor is it peculiar to fishes to employ their tail in the process of leaping; some quadrupeds, as the kangaroos, using their tails, in conjunction with their very long hind legs, to assist their bounds. Thus they not only employ an additional limb, the sudden extension of which, after flexion, adds to their impulse; but, pressing with an additional joint upon the fulcrum, they thus diminish any tendency which it may have to yield to the pressure which they impose upon it. Both in the kangaroo and the jerboa, or jumping rat, and also in the hare, rabbit, squirrel, and others, the muscles of the hind legs are also greatly developed, in order to give the force necessary to effect their extended leaps; while the fore feet, which are little employed in locomotion, are comparatively much smaller and shorter. In ascending a

THE KANGAROO.

hill this arrangement is very beneficial, though it greatly impedes these animals in descending one at a rapid pace; thus they seldom attempt to run down a hill in a straight line—their course is generally diagonal. Some insects, also, use their tail in leaping. This is the case with the velvet spring-tail, which leaps, by jerking its tail downwards from under its body, in the same manner as the grasshopper, the froghopper, or the flea, by jerking down its legs; that is to say, by suddenly extending them, after they have been brought to a state of full flexion.

PODURA.

Wonderful as may be the leaping of fishes, and much as the bounds recorded of these animals exceed those which man is capable of making, they fall very short of what we witness every day in insects—the grasshoppers and fleas, for example, being capable, with ease, of springing some hundred times their own length. Looking at the comparative lightness of these animals, however, and the favourable nature of the fulcrum on which they rest in making their springs, it is by no means certain that they employ more muscular power in their vaultings than fishes; while, on the other hand, it is pretty clear that they do not in general exercise them with anything like so definite a purpose, or so much precision.

It would be improper to leave this subject without remarking, that while some invertebrate aquatic animals—for example, the cuttle—are enabled to leap out of the water by the sudden extension, after flexion, not of their tails, but of their numerous arms or other processes from their bodies; others—for example, the oyster—effect the same action by suddenly bringing together the valves of their shells, by a strong muscle situated near the hinge, by which means a portion of the previously-contained water is rapidly expelled, and made to bear downwards upon that in the immediate vicinity of the animal, which, re-acting of course upon the sudden pressure, communicates an impulse which forces it above the surface. The feats of the oyster, however, in this way are very insignificant, and it is not easy to say for what purpose they are performed.

In conclusion, we would briefly remark, that so nicely and admirably are the organs of locomotion in quadrupeds adapted to each other, that an anatomist, from the inspection of any one bone of the very many which compose the skeleton—in man no less than two hundred and forty-six—is enabled to infer the general form and relations of all the rest, as well as of the ligaments which connect, and the muscles which move them. Nay, more:—so intimately does the structure of this shell, as it were, of the body correspond with that of the internal parts, that from this one bone he may almost give a description of every organ of the animal—of its propensities and its habits. Can this correspondence be the work of a blind chance? or does it imply a unity of design, an extent of benevolence, and a vastness of power, indicative of a ruling Providence—the Architect alike of the star of the firmament, and of the mite which plays in the sunbeam—whose hand is traced equally in the immensities of magnitude and of minuteness—the Almighty Father of the Universe, and of every thing that astounds and delights us in its construction?

◆

Senses of Animals.—The next function of which we have to speak is Sensation; and it will be convenient, in the first place, to devote a few pages to a short description of the senses in particular, and of the several organs by which, in different animals, the functions of smell, sight, hearing, taste, and touch, are respectively performed. We shall then pass to a general view of Sensation, Emotion, Instinct, and Thought; and conclude our subject with an account of Voice and Speech in Man, particularly as distinguished from the cries, song, and buzzing of inferior animals.

Smell.—In quite the lowest orders of animals the organ, if any, specifically appropriated to smell is in general very obscure, although some of them in which this is the case—the cuttle, for example—display this function very remarkably. It is, perhaps, in most of them, merely a modification of touch, and performed equally by every part of the surface of the body. In the snail the seat of smell has been commonly considered to be the short feelers; but apparently without any good reason.

Insects in general smell very acutely; and in them the seat of this function has been at different times supposed to be their stigmata, or air-holes, their palpi, or commonly-reputed organs of taste, and their antennæ, or organs of touch in general. In the crustaceans, as the cray-fish and lobsters, which are among the few of this order that have a sufficiently obvious olfactory nerve, it is manifestly their smaller antennæ, at the root of which the nasal cavities are situated. In these animals, however, as well as in all aquatic animals, smell is rather a modification of taste than a distinct function, the vehicle of the impression being not air, but water. Such is also the case in fishes; in them the nasal cavities are situated, in general, on the sides of the snout, and are lined by a plaited membrane, sometimes not unlike the teeth of a comb,

SPINY LOBSTER (*Palinurus*).

for the distribution of the proper nerve. The distance at which some fishes scent their prey is immense; and they are so acutely sensible of odorous bodies, that the very perfection of the function is often fatal to them. Some kinds of fish are so strongly allured by aromas, that by smearing the hand over with them, and immersing it in water, they will often flock towards the fingers, and may be easily taken. In all fishes, external openings, or nostrils, are very apparent. They generally constitute, it is true, only blind sacs; but their inner surface is of considerable extent, and upon their lining membrane, a pair of large nerves, analogous to the olfactory nerves of man, are distributed.

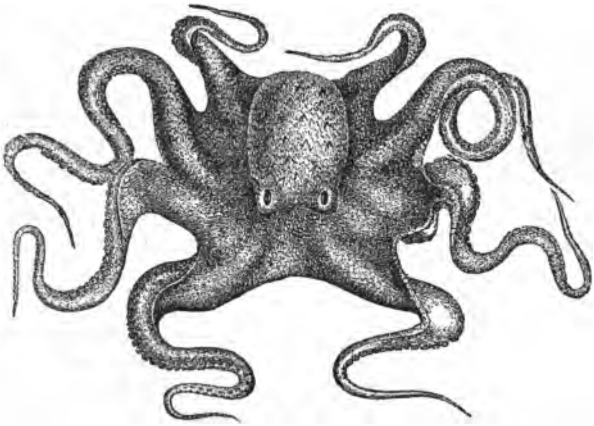
In reptiles, the nasal cavities have both an internal and external opening; the former being, in frogs, turtles, and serpents, in the palate; but in lizards, in some of which, as the crocodile, they are exceedingly long, in the pharynx, or muscular bag, at the back part of the mouth. Most reptiles, also, have a kind of a movable lid at the aperture of their nasal cavities, by which they close them when under water; this medium being apparently but ill-adapted in them to the function of smell. The proper vehicle of the impression in reptiles, as well as in birds and mammiferous animals, is air; and this the former draw through their nasal cavities during inspiration, effecting the operation by depressing their lingual bone, and thus enlarging the cavity of the mouth.

In birds, the nasal cavities are in general very large, their external aperture being in the upper mandible, and their internal in the pharynx. The olfactory nerve is very large in carnivorous birds, and its great size, together with the great length of the nasal cavities, serve to explain the immense distance at which some of them—the vulture, for example—are known to scent carrion: it is said to be capable of doing this over the whole breadth of the Mediterranean!

The nasal cavities of mammiferous animals run in general horizontally; but in the cetaceous tribes their direction is perpendicular, the outer opening being at the top of their heads. Many animals of this kind—as the porpoise, the whale, and the narwal—are generally regarded as destitute of smell, since they have no proper olfactory nerve; and certainly the hard and dry lining of their nostrils, like that of the proboscis of the elephant, is apparently very little adapted to this sensation. The projecting bones, by which the nasal cavities are, in most animals, more or less divided, are, in quadrupeds, extremely complicated, being, in most herbivorous species, both variously convoluted, and pierced sometimes like lattice-work, and, in most carnivorous, lamellated like the leaves of a book—a structure calculated, by increasing the surface, together with the great length in general of their snout, and the large size of their olfactory nerves, immensely to increase the acuteness of their smell. The "intellectual noses," as they are called by Lord Byron, of dogs are proverbial; and the distance from which many other quadrupeds, particularly such as are carnivorous, are sometimes attracted by the smell, is wonderful; white bears, for example, being found to come swimming to the Greenland ships, when a whale is cutting up, from all quarters, and far out of sight. Some quadrupeds, as the hog, the peccari, and the tapir—have a remarkable power of moving the extremity of their snout; but this is probably less for the purpose of smell than for that of burrowing, &c., their snout being to them, as its proboscis is to the elephant, a kind of hand.

In man, the sense of smelling is performed by means of a soft pulpy membrane, called the Schneiderian membrane, full of pores and small vessels, and lining the whole internal cavity of the nostrils; it is thickest upon the septum, or partition between the nostrils, but thinner in the sinuses, or cavities, hollowed out in the bones about the nose. The nerves of the nose being almost naked, require a defence from the atmospheric air, which is continually drawn through the nostrils, and blown out again by respiration. Nature has, therefore, supplied this part with a thick insipid mucus, very fluid in its first separation, but, by the air, condensed into a thick, dry, and more consistent crust. By this mucus the nerves are defended from drying and from pain. It is poured out from many small vessels, and deposited partly into numerous cylindrical pits, and partly in the round visible cryptæ or cells scattered all over the nostrils. This mucus is accumulated in the night-time; but in the day it either flows spontaneously, or may be more powerfully expelled by blowing the nose. By becoming dry and harsh, it irritates the very sensible nerves of the lining membrane, and is then removed by sneezing. The tears descend into the nose by a channel proper to the muscles, and moisten and dilute the mucus.

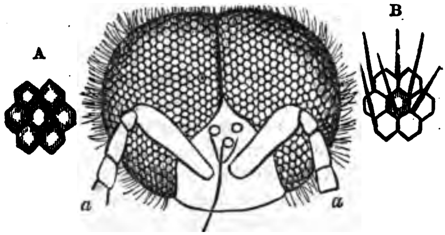
Sight.—With respect to sight, it is equally doubtful, as with respect to smell, whether there be any specific organ for this function in quite the lowest tribes of animals; although some of them, as the armed polype, the sea-feather, and some corallines certainly do see, or at least are capable of distinguishing light from darkness, the former being always found to move towards the light, and the two latter from it. It is, however, probably by a kind of touch that they do this, rather than by sight, properly so called; and of this the numerous papillæ on the surface of the body may be presumed to be the chief instruments; so, also, the first appearance of distinct organs of vision is that of stemmata, as they are called, or small knobs, more or fewer, projecting from the surface of the body, as is the case in the leech; and what are regarded as the eyes of the snail, are little more than similar knobs, placed at the extremity of their long feelers, and capable of being retracted by the muscles of the latter, into which they descend, as into the inverted fingers of a glove. Organs of this kind may serve, indeed, to distinguish between light and darkness; but it is impossible that they can convey any impression of distinct images of objects, since they have not the conditions necessary to produce such refractions of the rays of light as are essential to this end. Among the few animals of this description which are provided with proper eyes, is the cuttle-fish tribe, in which those organs are very large and prominent. They consist essentially of a dense opaque globular membrane—the sclerotic coat—filled with a



POULP, OR OCTOPUS.

transparent fluid, enveloping a small lens, and smeared on its concave side with a black pigment, the use of which is to absorb the superfluous rays of light, and immediately under which lies the retina or expansion of the optic nerve. This membrane is perforated anteriorly by a kidney-shaped pupil, through which the rays of light are transmitted to the retina; and over the whole is extended a second membrane, so folded on itself, as to constitute a kind of eyelid.

Similar to the stemmata of some worms are what are called the simple eyes of insects; and such are alone found in the spider and scorpion: they seem to be organs rather of touch than of sight, although they have been presumed by Blumenbach to serve to distinguish near objects. Very different from these are the so-called compound eyes of insects, such as are met with, without any simple eyes, in the beetle and butterfly; while others, as the bee, have both. They are for the most part extremely large; varying, however, between about one-sixtieth and one-fourth part of the weight of the whole body. Their structure is eminently beautiful; consisting, as they do, not of coats and humours, but principally of a series of pyramids of nervous substance connected together, the apices being on the bulbous extremity of the optic nerve, and the bases, invested each by a thick transparent membrane of a hexagonal shape, at the circumference of the eye. This membrane, presenting thus numerous facets, which look in every direction, is called the cornea, and seems to be in insects the only instrument of refraction, the images of objects being most probably impressed, by this means, directly on the base of each pyramid, which is thus a kind of distinct eye. They have no lens and no pupil, or rather the whole surface of the cornea is one large pupil, there being no opaque coats to render a proper pupil necessary; and they are destitute both of eyelids and of muscles to move the eye, the numerous directions of the facets of the cornea rendering the latter superfluous. How strikingly different is this description of eye which characterizes insects which fly, and require therefore an ample field of vision, from the simple eye found in the grovelling kinds, which either do not see, strictly speaking, at all, or certainly only quite contiguous objects! Further, in insects which fly by night, like the moth, there is, in place of the black pigment lately mentioned as found in the cuttle, a substance of a resplendent green or silvery colour, serving not to absorb, but to reflect the rays of light; and thus enabling them to see by a much more obscure light than would otherwise have been necessary.



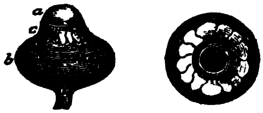
HEAD AND EYES OF THE BEE.
aa, antennæ; A, facets enlarged; B, the same, with hairs growing between them.

Among vertebrate animals, fishes have an eye somewhat similar to that of the cuttle; consisting essentially of a spheroidal sclerotic coat, containing the chief humour of the eye, a lens which, as in the cuttle, is almost globular, and a retina, which is often plaited, as it were, into numerous folds, arranged like the meridian lines on a globe. They have, however, in addition, a proper cornea like insects, presenting, not indeed numerous facets, but one uniformly convex surface, although the convexity is very slight; and they have further, what insects have not, a perfectly formed iris, or circular curtain, placed before the lens, in which, and not, as in the cuttle, in the sclerotic coat, the pupil is situated. The rays of light accordingly traverse, in these animals, first the transparent cornea, and afterwards, in order, the anterior portion of the humours of the eye, the pupil, the lens, and the posterior portion of these humours; by all which, except the pupil, they are more or less refracted, till they are at length brought to a focus on the retina. The chief peculiarity in the eyes of fishes, as contrasted with those of the superior tribes of animals, is the comparative flatness of their cornea, and convexity of their lens; it appearing to have been the object of nature to effect the necessary refraction of the rays in them principally by the latter; the iris, moreover, in fishes, is almost entirely motionless, so that the size of their pupil is always nearly the same. In general they are destitute also of proper eyelids; the eyeball moving behind the common integuments—to which it is attached by very relaxed cellular tissue—as behind a piece of thin glass or horn. In some few fishes, however, as the sun-fish, Cuvier has found a regular circular eyelid, the opening in which is contracted by a sphincter, and expanded by five radiating muscles. The direction of the eyeballs is usually outwards; but in some few fishes, as the star-gazer, it is upwards; and in the plaice, flounder, dab, halibut, turbot, &c., the eyes are placed both on one side of the body—an isolated instance, according to Blumenbach, of a want of uniformity in such organs. The object, however, of such an arrangement in this instance is obvious, for as these animals, destitute as they are of an air-bladder, are destined to continue always with one side in the mud at the bottom of the water, an eye on this side would have been superfluous to them. The most singular situation of the eyeball, however, is that of the Surinam sprat, the orbit extending in this fish so far above the head, that the eye, as the animal swims near the surface, is partly in and partly out of the water; and all its parts correspond with this strange structure, the pupil being partially divided into an upper and a lower portion, and the lens consisting of two globes, an upper and a lower one, attached together. It appears that the superior part of the eye is, like that of terrestrial animals, adapted to refract rays transmitted by air, and the inferior part, like that of aquatic animals, those transmitted by water; and that the refracting power of the several parts of the eye is accordingly much less above than below. It remains only to remark, that in some fishes, as the skate and shark, there is, as in insects that fly by night, a resplendent substance at the bottom of the eyeball, instead of the black pigment which is usually found there; its use being rather to increase than diminish the number of rays which fall upon it.

The eyes of reptiles in general do not differ materially from those of fishes, except that they appear to possess the power, of which those of fishes are destitute, of adapting themselves to refract rays as transmitted either by air or by water. We have already hinted, when speaking of the singular eye of the Surinam sprat, that the refracting power required is different in these two cases, as any one may satisfy himself by attempting to distinguish minute objects placed in water, with his head likewise immersed in this fluid. The reason that he cannot do this, is because, though there is a sufficient difference between the density of the humours of his eye and that of the air, to bring the rays transmitted by the latter to a focus on the retina, there is not a sufficient difference between the density of these humours and that of water, to do the same by rays transmitted through this fluid, so that such rays are not brought to a focus sufficiently soon. Hence, divers in some places are in the habit, when they descend into the water, of using extremely convex glasses, in shape almost like the lens of fishes, and turning their eyes, by this means, as it were, into those of an aquatic animal. But how do reptiles manage this? Not by using spectacles, nor by increasing the density of their humours;

but by increasing the distance between the cornea and retina—which they effect by compressing the globe of the eye by proper muscles given to them for that purpose—so that the rays which, from the defective refracting powers of their humours, would have otherwise formed a focus *beyond* the retina, now form a focus *upon* it. When again in the air they relax these muscles, and the retina again approaching the cornea, still receives the focus of the rays, which, as passing now through air, are sufficiently refracted for the purpose. Whether we regard, then, the heart and blood-vessels, the respiratory organs, or those of the senses, in these tribes, we trace equally distinctly the main object which nature had in view in their construction. The motions of the iris in reptiles—now for the first time perceptible—are still extremely languid, and the form of the pupil is very various, being rhomb-shaped in the frog, vertically oval in the crocodile, &c.; but this probably makes no difference in the phenomena of vision. With respect to eyelids, all reptiles are furnished more or less perfectly with these, except serpents, which, in being destitute of proper eyelids, resemble most fishes. The direction of the eyeball is, as in most fishes, commonly outwards; but in the crocodile it is, as in the star-gazer, a little upwards as well as outwards, obviously for the purpose of enabling the animal to see its land prey, as it floats leisurely just beneath the surface of the water. Reptiles have also, all of them, again excepting serpents, another organ which all fishes want,—namely, a lachrymal gland, the secretion from which serves to bedew the anterior part of the eye with moisture, and thus to facilitate the motions of the eyelids. Such an organ would evidently have been quite superfluous in fishes, which are always under water; but it is particularly necessary in amphibious animals, which, when on land, must furnish from their own resources a fluid so abundantly supplied to them when in the water from without. This gland is accordingly of immense size in turtles; and the allusion to crocodile's tears, as flowing easily and copiously, is familiar to everybody.

The eyes of birds are remarkable principally, like the compound eyes of insects, for their great size, the use of this being in both the same—that of enabling them, when on the wing, to see objects at a great distance. With respect to the cornea and lens, they are directly opposed to those of fishes; since, while the cornea is comparatively flat, and the lens almost globular in fishes, in birds the cornea is remarkably prominent, and the lens has very little convexity. The motions of the iris in most birds are extremely rapid, and in some apparently voluntary. The pupil is in some, as the dove and the goose, transversely oval, while it is vertically oval in others: generally speaking, indeed, it has the former shape in herbivorous animals, whether birds or quadrupeds, and the latter in carnivorous. All birds have proper eyelids, the lower of which alone is movable; and they have, in addition, another membrane called membrana nictitans, which is merely a movable fold of the external membrane of the eyeball: it is not quite proper to birds—being found also in some fishes and reptiles—but it is most remarkable in them. With very few exceptions—the owl among others—the direction of the eyeballs is, in birds, outwards. Such birds also, as well as insects and fishes, as go in search of their prey by night, like the owl, have a shining substance at the bottom of the eyeball, for the purpose already alluded to. In some birds with piercing sight, as the falcon and crane, the flattened optic nerve has one of its surfaces folded into numerous plaits,



LATERAL AND FULL VIEW OF EYEBALL OF OWL.
a, very convex cornea; *b*, sclerotic coat, surrounded at *c*, by bony plates.

bearing the same relation to the other as the leaves bear to the back of a book; and the extent of surface thus gained may be easily imagined.

Among the mammiferous animals, the cetaceous tribes, as we should expect from their habits, have eyes very similar to those of fishes; the cornea being comparatively very flat; and the lens almost globular, while they are destitute of proper eyelids—a kind of membrana nictitans alone supplying their place—and of a lachrymal gland. In the other tribes, the comparative convexity of the cornea and lens is intermediate between that of these organs respectively in fishes and birds; while the motions of the iris are the mean, as it were, of those of reptiles and birds: in some quadrupeds, moreover, as the cat, they seem to be in some degree voluntary. The form of the pupil is transversely oval in the pecora and solidungula, and vertically oval in the Feræ. The direction of the eyeballs is in most mammiferous animals outwards; in the ape, however, baboon, monkey, and some few others, it is, as in man, directly forwards: further, in some quadrupeds, as the camel-leopard, the eyeball, though naturally directed outwards, may be turned so far backwards as to enable the animal to see distinctly behind it. Like the nocturnal animals, also, of other tribes, quadrupeds which prowl by night, such as the lion, lynx, cat, bat, &c., have the structure as already more than once described, calculated to enable them to distinguish objects in comparative darkness. On the other hand, where the habits of the animal are such as to exclude it altogether from the light, as no structure of the eye could have compensated for the want of this essential condition of sight, nature has denied them a visual apparatus altogether—as in the case of the mole, which has no optic nerve, and an eye so small, that its existence has been doubted; but whatever be its size, in all animals the eye is a perfect optical instrument, and admirably adapted to the circumstances in which each species is placed. We know it to be composed, as we shall hereafter see, of membranes and humours of different densities, so that they may transmit and refract the rays of light with the greatest regularity and exactness. In the eyes of all animated beings, we see the wisdom and beneficence of the Creator. If the animal dwell in water, the cornea is flat, and the lens spherical; if on the surface of the earth, we find, on the contrary, the cornea more projecting, and the lens more flat; and again, if it wing its airy flight above us, its cornea is the most projecting, and its lens the flattest of all.

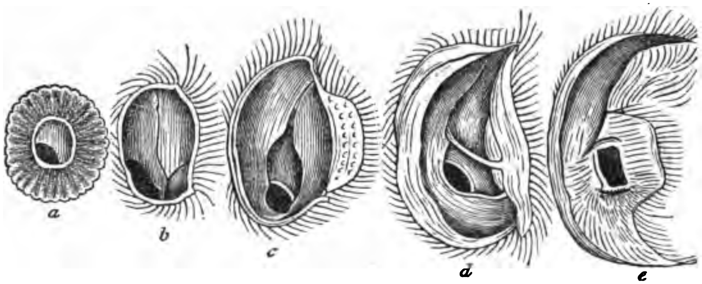
Hearing.—In the very lowest tribes of animals it appears that this function, like those of smell and sight, is merely a more delicate kind of touch, and performed equally by the whole surface of the body. The greater number of animals of this description have no obvious auditory apparatus, the cuttle being among the few exceptions, and furnishing perhaps the best example of an ear in its rudimental state. In this animal it consists merely of a membranous bag filled with liquid, situated in a tubercle of the cartilaginous ring which surrounds the gullet, and surrounded on all sides by cartilage. Upon the outer surface of this bag is distributed the auditory nerve; while, within the liquid which it contains, are some little pieces of earthy matter, presumed to be necessary to render the vibrations of the liquid, on which sound depends, sufficiently forcible to make the requisite impression on the nerve.

In the greater number of insects, also, the auditory apparatus is very obscure; although it is certain that they do hear, and even very acutely. The immediate seat of the function has been presumed to be the membrane which connects their antennæ with the head—but spiders hear which have no antennæ, and grasshoppers after these have been removed. In all likelihood, it is, in the majority of insects, merely a variety of touch, and common, therefore, to the greater part of the surface. In such animals as present any appearance of a distinct auditory apparatus, as the crayfish, it is very similar in its structure to that of the cuttle; consisting, in like manner, of a bag filled with liquid—situated, in this instance, in a bony cylinder at the root of the larger antennæ—an auditory nerve expanded upon it, and some pieces of earthy matter in the liquid which it contains. In the cray-fish, however, unlike the cuttle, the bag in question is not surrounded on all sides by the hard mass which contains it, but is near the surface of the body, in contact with a thin membrane—the first approach to the external parts of the auditory apparatus, as met with in the higher tribes of animals.

Nor is the auditory apparatus of most fishes much less simple than that of the invertebrate animals. The membranous bag, however, above spoken of, is connected in general with three semicircular canals, of a similar structure, and furnishing more space for the distribution of the auditory nerve; and the earthy pieces, within the liquid contained in this bag, have begun to assume the appearance of regular bones. Still, in most fishes all these parts are buried within the skull, and send no process to the surface; in some of the cartilaginous tribes alone this bag being prolonged to the upper and back part of the head, where the blind termination of it is covered by the common integuments of the body. One fish alone—the lepidoleprus trachyrynchus—presents any appearance of a canal, proceeding from the surface to meet the internal parts, as in all animals above the rank of reptiles. But the extreme simplicity of the auditory apparatus in fishes and other aquatic animals, is precisely what we should have looked for in beings destined to hear through the medium of water; the vibrations of which, being so much more powerful than those of air, would render the complicated apparatus, requisite in terrestrial animals, in them superfluous.

Accordingly, it is in reptiles that we meet with, for the first time, more or less constantly, not indeed a canal leading from the side of the head towards the ear—which none of them have—but one leading from the back of the pharynx, to form a cavity, interior to which all the parts already described are situated. This cavity is called the tympanum, and contains more or fewer distinct bones, moved by proper muscles, and serving to increase the impulse derived from the vibrations of the air, and to convey it to the internal parts, which now take the name of labyrinth. Some additions, also, are now made to this; for, besides the three semicircular canals, already described as branching from the common bag in one direction, there is now a second series of canals, of a very complicated structure, called cochlea, branching in one another, and affording, of course, still further space for the expansion of the auditory nerve. It is true these parts are not common to all reptiles; serpents, for instance, having no tympanum—although they have a small bone, analogous to those which, in other reptiles, are situated in this cavity, but which, in serpents, is lost in the muscles of the jaws—and none but some of the highest orders of lizards, as the crocodile, having a cochlea. The last-named animal, moreover, makes the first approach to the well-known appendage to the ear, technically called the pinna; being furnished with a kind of external flap, with which it closes the auditory apparatus at pleasure. It is in this way, probably, that the animal excludes too intense sounds when under water; but it appears that the greater number of amphibious animals are capable of adapting their auditory apparatus, at least partially, to the medium in which they are, by putting all the parts upon the stretch, by means of the muscles already spoken of, when in the air, so as to qualify them to receive slighter impressions, and by throwing them all into a state of relaxation when under water, so as to prevent them from being stunned by more powerful ones.

In birds at length we meet with constantly a short canal, leading from the side of the head, and meeting that coming from the pharynx, in the tympanum. They have but one bone in this cavity; and the general structure of the parts of their labyrinth is very similar to that of the higher orders of reptiles. Birds in general want a proper pinna, or ear-flap, its place being commonly supplied by a small tuft of feathers: the owl, however, has something very similar to this part as found in mammiferous animals.

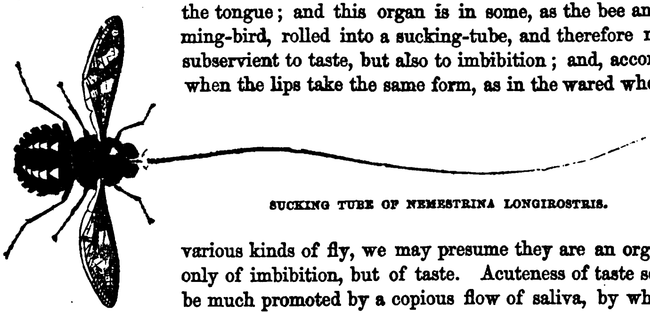


EARS OF BIRDS.
a, Peregrine Falcon; *b*, Day owl; *c*, Tawny owl; *d*, Long-eared owl; *e*, Barn owl.

The auditory apparatus of the mammalia is in general little more than a greater development of the same parts as are found in birds. The bones within their tympanum are from two to six in number; and all have a pinna except the cetaceous tribes—in which it would have been superfluous, from the vibrations of water being too strong to require to be collected by this means—and some others, which either dwell much in the water, as the shrew, or burrow under ground, as the mole, in which, for an obvious reason, it is still less called for. The shrew, however, is provided with a kind of flap, like that of the crocodile, the principal use of which seems to be, so far from increasing the intensity of the impression, to diminish it when the animal is under water. The great size of the pinna in some quadrupeds, and the frequency and rapidity with which they move it in any direction, are familiar to everybody; and may well account, in conjunction with the complicated and delicate structure of the internal parts of the ear, for the extremely acute hearing which they enjoy, and which is so necessary, in many instances, to their security. Hence, a frequent and rapid motion of the ears is, in all animals, with justice regarded as indicative of a timid disposition. We do not here allude to the organs of sight and of hearing in man, since their description will more appropriately fall under our treatises on Optics and on Acoustics.

Taste is certainly, not only in the lower, but in all tribes of animals, merely a more delicate kind of touch; and is situated, for the most part, not exclusively in the tongue, palate, or any other individual organ, but in the whole interior of the mouth.

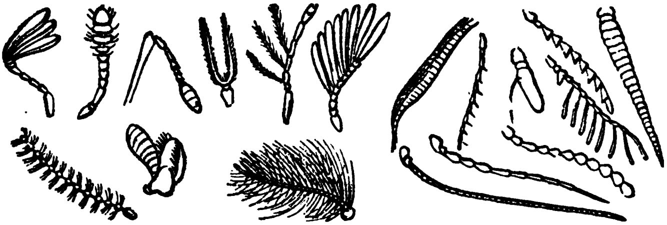
Although, therefore, in many animals, as the snail, cuttle, and fishes in general, as well as in some individuals of the superior classes, the tongue is hard and cartilaginous, and apparently very little adapted to this function—nay, although it is, as in the flying-fish and gar-pike, altogether wanting—we have no reason to believe that they are destitute of taste; and the same thing may be said of the numerous animals in which the tongue is covered, more or less perfectly, with prickles, or even with feathers, like the toucan, or scales, like one kind of bat, which must, in a great measure, obviate the contact with it of sapid substances. The immediate instrument of taste seems to be certain pointed projections, called papillæ, with which the whole membrane lining the mouth is more or less abundantly furnished; and that organ will be, of course, in all animals the principal seat of this function, on which these papillæ are most copious. In man this is the tongue, the papillæ of which are larger and softer than those of the skin, perpetually moist, and performing the office of touch more exquisitely than the small and dry cutaneous papillæ. In the greater number of animals, also, it is unquestionably the tongue; and this organ is in some, as the bee and humming-bird, rolled into a sucking-tube, and therefore not only subservient to taste, but also to imbibition; and, accordingly, when the lips take the same form, as in the wared whelk, and various kinds of fly, we may presume they are an organ, not only of imbibition, but of taste. Acuteness of taste seems to be much promoted by a copious flow of saliva, by which the sapid particles are dissolved; and it may be presumed, therefore, that it is much greater in the herbivorous than in the carnivorous birds and quadrupeds, as indeed the necessity which the former are under, but from which the latter are exempt, of distinguishing wholesome from deleterious herbs, would seem to require. Carnivorous animals, on the other hand, are directed to their food principally by the smell.



SUCKING TUBE OF NEMESTRINA LONGIROSTRIS.

Touch—the most general of the sensations, and of which all the rest are perhaps only varieties—is, collectively speaking, the whole surface of the bodies of animals; although it is in each much more delicate in certain parts of this surface than in others, owing to the greater number of papillæ with which they are furnished, and which are generally the immediate instrument as well of touch as of taste. The common integuments of the bodies of animals in general consist principally of the scarf-skin or cuticle; a substance immediately below this, called corpus mucosum, of which the nails and hairs are merely modifications; and the true skin or cutis, the seat of the papillæ in question; and there are few animals, even of the lowest tribes, which have not all these envelopes in one form or another. In the armed polype indeed, the sea-blubber, the slug, the earth-worm, and many similar animals, the cuticle takes the form of mere mucilage; while in the corallines, on the other hand, it assumes that of a calcareous mass, by which their bodies are invested. In others, again, it is the corpus mucosum which gives them their earthy covering, a proper cuticle being found exterior to it, as in the sea-urchin, the star-fish, and all the testaceous tribes: the sharp prickles, also, on the shell of the sea-urchin, as well as the hairs of the earth-worm, and numerous other animals of this tribe, are merely modifications of the same substance. A proper cutis seems, indeed, to be wanting in the corallines, as well as in some other animals of quite the lowest orders; but in the testaceous tribes, as the oyster, the cloak is probably a modification of this part, and it is accordingly upon this, or some corresponding organ, that the tentacula, or immediate instruments of touch, are commonly met with. The perspiration from the surface seems to bear the same relation to touch as the saliva bears to taste; and there are, therefore, few animals which do not perspire in one form or another. In some of these tribes, as the sea-blubber, the perspired matter is said to be luminous; and it is to this cause that the sparkling appearance of the sea by night in some places has been attributed.

In insects, the cuticle is always membranous; while it is the corpus mucosum which constitutes their horny or calcareous sheaths, and forms, also, in some, as spiders, flies, gnats, bees, and butterflies, the fine hairs, feathers, or scales, with which they are in certain parts invested. The proper cutis, again, is below this, constituting, in the lobster, for example, its membranous pellicle. This part is, however, so completely defended, for the most part, from the contact of external substances, that to most insects are given in addition antennæ, palpi, cirrhi, &c., called in general feelers, situated commonly about the mouth, and the chief seat, in them, of the function of touch.



VARIOUSLY FORMED ANTENNÆ OF INSECTS.

The cuticle is membranous also in fishes, and immediately invests their scales, as well as the bristles of the stickleback, the tubercles of the sturgeon, &c., all which are formed by the corpus mucosum. Under this is the cutis.

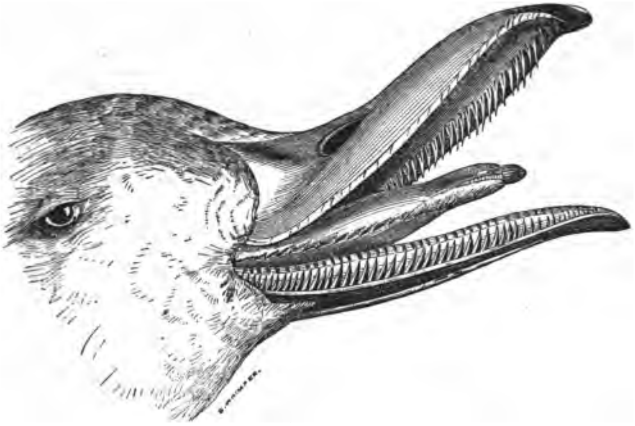
Not only are the smell and taste of fishes very acute, but their touch not less so than that of animals in general. It is astonishing, however, what an extreme degree of heat some fishes can bear. In the thermal springs of Bahia, in Brazil, many small fishes were seen swimming in a rivulet which raised the thermometer eleven degrees and a half above the temperature of the air. Sonnerat found fishes existing in a hot spring at the Manillas at a hundred and fifty-eight degrees Fahrenheit; and Humboldt and Bonpland, in travelling in South America, perceived fishes thrown up alive, and apparently in health, from the bottom of a volcano, in the course of its explosions, along with water and heated vapour that raised the thermometer to two hundred and ten degrees, being but two degrees below the boiling point.

The bodies of most fishes are covered with small brilliant plates of a horny nature, called scales; but in certain kinds these are wanting, as in the turbot, in place of which are found osseous or cartilaginous protuberances in some species, and in others a very smooth skin, without scales or rugosities, but covered with a thick gelatinous secretion. It was observed by Steno, in the skate, that this slimy matter was poured out from numerous orifices regularly placed near the surface; and Dr. Monro has recorded his discovery of a very elegant structure for the preparation of this mucus between the skin and muscles. The secretion is so viscid that it is with great difficulty pressed out. There is a species of carp—the rex cyprinorum of Linnæus—that seems to hold a middle place between the rough and smooth skinned fish; the upper part and back is covered with scales, while these are altogether wanting on the lower part and belly.

In reptiles the cuticle is either membranous, or, as in the frog, consists merely of mucilage, as it does in many worms already noticed. The corpus mucosum in these animals assumes the form either of a soft viscid substance, as in frogs; of a horny shield as in tortoises; or of scales, as in serpents and most lizards; some of the latter, however, as the crocodile and alligator, have it again in the form of hard plates, like the shields of tortoises. It is of the corpus mucosum, also, that the claws of such reptiles as have them are constituted. The proper cutis is situated under this; and as the papillæ of this organ are most numerous about the soles of the feet, we must conceive that it is in this part principally that the touch of reptiles is resident.

The perspiration of reptiles is in general very copious; that of the salamander, for example, being so much so, as to extinguish flame, and thus to have given rise to the fable of its being capable of living in the fire. In some, as the toad, the perspired matter is of a poisonous quality; and in one kind of lizard it is so acrid as to blister the fingers.

In birds, the cuticle is again membranous; while the corpus mucosum assumes the form, upon the mandibles, of a bill; upon the body in general, of feathers; upon the legs, of scales; and at the extremity of the toes, of claws. Under this is the cutis, which, abounding in papillæ, most in general below the bill, particularly in the swan, goose, and duck, may be presumed to render this organ the most sensible to external impressions.



BILL AND TONGUE OF WILD DUCK (*Anas boschas*).

In mammiferous animals, the membranous cuticle covers a corpus mucosum, generally of a soft viscid consistence, but in some few animals of this class, as the rhinoceros, armadillo, scaly ant-eater, &c., assuming the form of hard plates, like those of the crocodile and alligator. It is of the corpus mucosum, also, that are constituted, in some few, as the duck-billed animal, a perfect bill; and, in the greater number, the hair, fur, wool, bristles, quills, &c., with some one or other of which their bodies are covered; as well as the horns, claws, hoofs, &c., with which many of them are furnished. The cutis, lying under this, is, in all, the organ of touch; which is most acute, in the duck-billed animal, upon the bill; in the carnivorous tribes, at the root of the whiskers; in those with movable snouts, as the mole, hog and elephant, upon that organ; in the bat, upon the membrane between their fingers, commonly called their wings; and in most of the Glires, as the squirrel, as well as in apes and other animals of this description, at the tips of the fingers; since it is in these organs respectively that the papillæ are most abundant. It is unnecessary to point out how admirably this corresponds with the habits of each of these animals; and the delicacy of touch which some of them enjoy in the organs in question is wonderful—an elephant, for example, being able to distinguish, by the tip of its trunk, between the most minute objects, and a bat being capable, though deprived of the use of its eyes and ears, to direct its rapid flight through the most intricate places, the touch alone of its membranous wings sufficiently apprising it of the contiguity of objects, and thus enabling it to avoid them.

Consciousness.—The animal functions, or functions of relation, are currently spoken of as the functions on which consciousness peculiarly attends. The states of consciousness are the various states of animal being in which the sense of existence is present. Thus every exercise of mind in man is properly described as a state of consciousness. All his sensations, emotions, appetites, and desires, are so many states of his consciousness; since the feeling of existence is an essential element in all these several affections. The exercise of locomotion, in obedience to volition, is a state of consciousness; and even involuntary acts, such as yawning, sighing, hysteric laughter, and the like, come under the head of conscious acts, or acts into which, as an element, the sense of existence enters. Hence, it may be inferred, that, in the lower animals, acts of pure instinct, altogether independent of anything like volition, are often states of consciousness. Thus man's animal existence is made up of a long succession of states of consciousness, scarcely altogether interrupted even during sleep.

The analysis and methodical arrangement of such states of consciousness constitute the proper business of the philosophy of the human mind. Of locomotion and the senses of animals we have already briefly spoken; and, for the present, a few words must suffice on sensation, emotion, reason, instinct, and thought.

Sensation is a mental feeling, or state of consciousness, to which, however, certain corporeal preliminary conditions are essential. When the point of a needle makes the slightest puncture at the surface of the skin, a sensation takes place. The feeling of pain combined, if one so may speak, with a sense of existence, constitutes this sensation, distinctly entitled to be termed a state of consciousness. But there is also another element in such a sensation, which does not manifestly enter into every state of consciousness. That other element is, that the consciousness has a local seat; that the consciousness of pain is felt to exist at the point where the needle has pierced the skin. But anatomy quickly teaches us that the sensible point which the needle touches, is not the independent, although the manifested seat of sensation. It is found, that such a point of the surface of the body only remains sensible on condition that nervous filaments extend to it from the nervous centre, that is, from the brain or spinal marrow; that such filaments are entire and unbroken; and further, if such filaments be divided, compressed, or otherwise seriously injured, that a needle may be thrust into the part without the production of any mental feeling whatever. In short, it is discovered by a little investigation, that when an impression, such as that made by a needle, affects the extremity of a nervous filament, a corresponding change occurs in the point of the brain, or spinal marrow, to which that nervous filament extends; and that this change in the nervous centre fails to occur, unless the nervous filament concerned be entire in its whole extent. The singularity here to be observed, is, that although the point in the nervous centre is plainly that on which the mental feeling depends, yet that that mental feeling is not felt to have any local existence, except at the extremity of the nervous filament touched by the needle. Thus the seat of sensation, the local seat of the state of consciousness, which constitutes a sensation, is always in the organ, or part of the body, where the nervous filaments concerned terminate. It is quite true, as Epicharmus sung:

> "Mind it seeth, mind it heareth—
> All beside is deaf and blind;"

nevertheless, the felt local seat of sensations is in the skin, the membrane of the nostrils, the membrane of the tongue, the labyrinth of the ear, the retina of the eye, and finally, in the locomotive organs in general, when brought into action.

The mind has, indeed, no local seat. It would be absurd to speak of a spiritual essence as having parts, or being in connexion with space; but, nevertheless, it is quite certain that in sensation the mind manifests itself in what are termed the organs of sensation. Here it is, then, in the skin and the other organs of sensation, that the confines of mind—so to speak—and the confines of matter meet. Nor is it erroneous to say that it is in sensation that mind communicates with matter. This view leaves the spirituality of the sentient principle wholly untouched. For, as Sir William Hamilton remarks (REID's *Works*, p. 862), "the connexion of an unextended with an extended substance, is equally incomprehensible, whether we contract the place of union to a central point, or whether we leave it co-extensive with organization."

The notion of extension, or rather the capability of forming the notion of extension, is undoubtedly an original endowment of the human mind; but the realization of that notion, there is little reason to doubt, takes place as the infant gradually notes the variety in the local seats of the many sensations continually occurring in his consciousness. In short, as Aristotle taught, the infant's body is contained within his soul in the exercise of sensation.

Besides sensations, there are no other states of consciousness which have a manifest local seat, unless that be said in a somewhat different sense of certain emotions. For, there are motions which are very constantly attended with certain bodily feelings, which feelings, on investigation, are discovered to be sensations arising during the exercise of certain muscular acts, which become, as it were, the signs of those emotions. All expression of emotion, whether calm or passionate, consists in certain movements of the locomotive system; and such movements of the locomotive system are attended, like the action of muscles in general, with sensations originating in the effect produced on the nervous sentient filaments of those muscles by the physical changes which they then undergo. Hence it appears that emotions themselves are not states of consciousness having a local seat; but that many emotions are accompanied by muscular acts which originate states of consciousness, or sensations having a local seat.

To such consecutive sensations, the name of sensations of emotion has often been given.

Emotion, in a larger sense, may include not only passions, but also desires, and, owing to their analogy with desires, even appetites. These constitute the impulsive part of human nature—leading to action too often with a vehemence overpowering all reason. All the bodily acts which result from emotions, passions, desires, and appetites, are doubtless attended with corresponding sensations; but, like those already mentioned, these localized states of consciousness are consecutive—not identical with these affections.

In proportion as man in society learns to control the impulsive part of his nature chiefly by the influence of reason, he advances in civilization. In the words of Ovid:—

"Et quod nunc ratio, impetus ante fuit."

Reason represents, collectively, the faculties, properly termed the Intellectual Faculties. Reason, however, implies the previous accumulation of knowledge, however slender, by comparison with that store of which man is capable. It has been well described as the action of the mind upon its knowledge. "Its power," says Isaac Taylor, "over itself, a power directed by knowledge, and employed for the accomplishment of some purpose foreseen, is what constitutes reason." Reason, by the knowledge of the past, consults for the future, putting a restraint upon present impulses. Reason, by reference to what the memory can supply from the past, combines the means suitable to effect ends, and; not discouraged by repeated failures, changes and improves these means till the end is accomplished, as often as that is attainable. By reason, also, it is often determined that such and such ends are not attainable by the means actually within reach. Thus reason is not so much a single faculty as a power of combining the operation of all the intellectual faculties towards the attainment of the object in view.

The first men, beyond question, had no other shelter from the scorching rays of the sun, and the rains, and the blasts of heaven, than the woody thicket, or the natural caves of the rocks and mountains. To this day, near the banks of the Jordan, there are tribes who live in mountain caves. In Borneo there are races who live in trees, like monkeys. There are African princes who hold their audiences in Nature's own palace, under the shade of the gorgeous banyan. Let us suppose that a party of primitive men had strayed to a place affording the shelter neither of a thicket nor of the mountain cave, and that the heat of the sun, or the season of rains, caused them annoyance; then would arise the exercise of reason,—the first display of man's building talent. The inconvenience he suffers from the loss of his accustomed shelter, carries his thoughts back to the form of that shelter. Let us first suppose that his original shelter was a cave. It is not any inward impulse which leads him to fix poles in the ground, inclined to each other at the top for mutual support, and to cover these with the skins of the animals he has killed for food, or with the large leaves and twigs he can collect around. But the desire to produce the likeness of his former cave raises a train of thought, in which are presented all such observations of his past life as bear on his purpose. The minute recollection of these stirs him on to the work, and, after failing and succeeding by turns, he at last, with repeated trials, constructs a rude tent, or hut, on the model which originally arose to his mind. It is by the imitation of what had before been seen that reason acts in such a case. In short, here reason acts on the knowledge before accumulated, so as to apply it to the purpose in view. Here reason appears in its proper character; not as a single faculty, collateral with memory or imagination, but as the master of the faculties; that which controls and compels the subordinate powers each to contribute its proper share to the work.

Had the party referred to never seen a cave, but been accustomed to the shelter of trees, the first tent would necessarily take more of the form of a tree; and were the model tree a banyan, we must suppose the tent would have been in the shape of a huge umbrella, supported at the circumference with slender posts, and in the middle by a stout pillar, corresponding to the central stem and descending roots of that singular production of the vegetable kingdom.

Instinct.—How different is instinct! Instinct is an agency which performs blindly and ignorantly a work of intelligence and knowledge. Many animals, particularly birds and insects, construct works to which, at first sight, there would seem to be requisite no small degree of forethought, knowledge, and calculation. In short, to produce such effects as are produced by many animals, an intimate knowledge of the principles of mathematics, and of the laws discovered by man in the physical sciences, would seem to be essential. Does any one believe that such knowledge and such faculties as are necessary for the construction of the honeycomb, reside in bees in the same sense in which it is said that such knowledge and such faculties belong to a man who is possessed of them? "It would take," says Sidney Smith (*Moral Philosophy*, p. 243), "a senior wrangler at Cambridge ten hours a-day, for three years together, to know enough mathematics for the calculation of these problems, with which not only every queen bee, but every undergraduate grub, is acquainted the moment it is born."

It is not, however, sufficient, with Isaac Taylor, and many other authors, directly to impute the knowledge and the forethought to the Creator; because we are required, in studying such a subject, to consider all the laws regulating such acts in the organic kingdoms, and endeavour to ascertain, before such a direct reference is made to the power of the Creator, how far the instincts of birds and insects, by which so many wonderful effects are produced, are not merely a part of a larger law which operates in that part of nature as a whole. The final reference, of course, is to the power of God, whatever be the result of our inquiries.

It is now many years since it was observed in man and animals, in general, that certain impressions made on the organs of sense, or on sensible parts of the body, are succeeded by muscular acts, sometimes of a very complex kind, performed altogether independently of the will. It was not at first observed, that on many occasions impressions might be made on many parts of the body, such as give rise to complex muscular acts of this kind, not only independently of the will, but even without any consciousness on the part of the individual that such impressions had been applied. Such, however, is the case. The nervous system is so constituted that certain impressions made on the extremities of nervous filaments, terminating chiefly on the surfaces of the body, are succeeded by the determination of influences, through other nerves, to muscular organs, by which these organs undergo movements on a definite plan, and often of a very complex kind. When no consciousness attends the impression, so that the affection of the nervous centre thereby produced fails to possess the character of a sensation, the effect is what gave rise to the idea of reflex actions, not accompanied by sensations, having their origin in the spinal marrow, in which plainly resides the power of determining certain complex muscular acts, on being affected by impressions conveyed through certain means. But all such muscular acts as originate in impressions made on the extremities of nervous filaments, independently of volition, whether accompanied by consciousness of the impression, or unaccompanied by such consciousness, are conveniently termed reflex acts.

This view of the nervous system in higher animals, for which we are chiefly indebted to Dr. Marshall Hall, though it does not explain, serves very much to illustrate the nature of instinct. According to the expression of a distinguished physiologist, Prochaska, "Peculiar laws are written, as it were by nature, on the medullary pulp;" and such and such impressions, conveyed by nerves to the nervous centre, whatever it may be, in the animal, call forth particular acts, in obedience to such originally written laws.

In short, the various acts of instinct in birds and insects, according to this view, present no greater difficulty, or, at the most, one not very much greater, than the numerous reflex acts subservient to the well-being of the body, varied as these constantly are in man and animals, under successive changes of circumstances. Such acts, and instinctive acts, fall under the same great law of the nervous matter — a law unquestionably originally impressed upon it by the fiat of the Creator. "As, then," says Dr. Bushnan (*Philosophy of Reason and Instinct*), "certain organic acts are the direct effect of sensation, so it will be found that instinctive acts, properly so called, can be traced to the same cause, and are, like them, dependent either on external or internal stimuli." The great sources of instinctive acts in the lower animals, are the senses of smell and taste; by which, particularly the former, they are led to select food which is salutary, with a certainty which far exceeds the boasted knowledge of man. There is scarcely a plant which is not refused by some, while it is eagerly sought after by others; and as many of these plants are highly poisonous to man, we must here draw the striking conclusion, that when the instinct of an animal leads it to eat of a plant poisonous to others, the law which so directs it, through the unconscious nervous centre, must embrace the fact that the poisonous chemical principle of that plant is destroyed by the peculiar digestive power of that animal.

Finally, among the sources of sensation on which instinctive acts are dependent, are various qualities of the atmosphere at different seasons, the periodical returns of appetites, and particularly of the sexual desire, the sense of ungratified want, the consciousness of muscular action, and, in higher animals, the presence of all kinds of emotion.

Thought.—When spoken of in connection with the functions of relation, Thought has an extensive signification. It is then contrasted merely with sensation; so that sensation and thought are often employed to include all mental phenomena. Such a use of the term thought, is, however, merely for the sake of temporary convenience; since emotions, passions, desires, and appetites—all of which are states of consciousness, distinct from sensations, can with no propriety be deliberately regarded as thoughts. If, however, from the whole succession of a man's states of consciousness we subtract his sensations, his emotions, his passions, his desires, and his appetites, then those states of consciousness which remain, will be such as are most appropriately termed thoughts. Thus, then, an act of memory is a thought; an act of conception is a thought; an act of abstraction is a thought; an act of imagination is a thought; an act of judgment is a thought;—and to think is specially to determine, with some definite purpose, successions of these several kinds of acts.

When a person thinks over a subject, he puts it in all possible lights, endeavouring to find out each new relation in which it stands;—that is, making use of what he has observed as to the modes in which one thing suggests another, he makes those things which rise spontaneously in his mind, the means of bringing up other things which were less obviously connected with his first thoughts.

Thinking, then, is a succession of acts, only in part voluntary. A man cannot call up any thought at pleasure unless within very narrow limits. But when he has once got possession of a thought, by dwelling on it, and considering its several connections, he may be secure that it shall arise whenever certain other thoughts shall have first occurred to his mind. When a man thinks correctly on any subject, it is very much the same as to say he exercises reason on that subject. For, to think correctly, he must exert a certain control over his thoughts, rejecting those which are vain, frivolous, and not pertinent to the subject, and detaining those in the contrary predicament. Still the mere expression to think has no constant reference to the exercise of reason; since one may be said to think in the larger sense when the thoughts suggested to the mind by some subject rise freely, whether they be to the purpose or not. Thus it is quite correct to say, that a man thinks incorrectly; and in so thinking he may have exercised actually as much voluntary control over his thoughts, as in any profound and just meditation. But to say that a man exercised his reason incorrectly, involves a contradiction. Thus, to think and to exercise the reason, are not one and the same thing. The reason, indeed, cannot be exercised without thinking; but much thought may pass through the mind with very little exercise of reason.

What is commonly called a train of thought presents this term in its widest signification. We say currently a train of thought is dependent on the association of ideas. But, when a train of thought is reviewed—for example, such a train as constitutes a reverie—it is found to consist not merely of the states of consciousness commonly called thoughts, or of those expressed by the term ideas, but of states of consciousness of every known kind—sensations, memories, abstractions, conceptions, imaginations, judgments, pity, remorse, anger, jealousy, ambition, desire. And each of the states entering into such a train is linked or associated with the states adjacent to it in the succession; so that what is usually called the association of ideas, is really the order in which the succession of every kind of consciousness happens at any one time to be determined.

Every man has his trains of mental phenomena, to a certain extent, under his own power, and this is the foundation of all self-education, or rather the foundation of all moral and intellectual education. It is quite possible that a child may be so reared as to be incapable of conforming the conduct of after life to the standard of morals required by the laws of his country. This person is exactly in the condition of him who labours under moral insanity. Had the dispositions, in childhood, of such a person been restrained by judicious management, then the passions, desires, and appetites would have been reduced within those bounds which reason requires. When the natural disposition is such, that under the best direction a child grows up, totally incapable of subjecting his moral nature to the control of reason, then that person is morally insane from birth.

The intellectual nature is perhaps less under the control of management than the moral nature. Nevertheless, education is capable of greatly extending the range of thought, and, within somewhat narrow limits, of giving to it greater justness and exactness than naturally belongs to the individual.

The benefits of training, whether by the education imparted from without, or by the efforts of the individual himself towards self-improvement, are manifestly dependent on the changes accomplished on the natural succession of the states of consciousness, or, in common language, on the natural succession of thoughts. And it is manifest that the more any one has indulged in incorrect thinking, or in licentious wishes, before the corrective of training is applied, the more difficult it must be to bring back the current of his intellectual and moral nature to that which reason directs. Correct thinking, intellectually and morally, is the only foundation of just judgment and blameless conduct:—

> ——————— "For since the course
> Of things external acts in different ways
> On human apprehension, as the hand
> Of nature tempers to a different frame
> Peculiar minds; so, haply, where the powers
> Of Fancy neither lessen nor enlarge
> The images of things, but paint in all
> Their genuine hues the features which they wore
> In nature—there opinion will be true,
> And action right."—AKENSIDE.

The next and last function we have to consider is that of speech, or the sounds which are produced in the larynx or vocal apparatus at the moment when the air traverses this organ, either to enter or to pass out of the trachea or windpipe; and we shall distinguish speech in man from the cries, song, and buzzing of inferior animals.

Voice.—Without the possession of voice how different would have been the history of man's progress on the earth! We can hardly conceive any other effectual kind of speech except that to which voice is subservient. Without articulate sounds man could hardly have risen to the rank of an intelligent thinking agent. By means of expression and gesture he might have communicated to his fellow-men no small share of his present desires, his present feelings, and even his present rude ideas; but under such circumstances how little of the past—how little of the future—would have entered into his mental existence!

Speech, then, may be justly regarded as one of the principal foundations of man's greatness upon the earth; and thus voice, speech, the cries of animals, the song of birds, and the buzzing of insects, present, in a physiological point of view, a succession of themes of the most engrossing interest.

In physiology voice is distinguished from speech, though without voice there is no perfect speech. This point deserves a word of explanation. When a person can speak only in a whisper, he is said to have lost his voice; that is, he has lost the power of utterance with that loud, thrilling, vibratory sound which constitutes perfect voice. But if whispering were man's only natural mode of speech, then we should not be entitled to say that man had no voice, but only that his voice was a soft, hissing, non-vibratory sound.

Voice, then, whether it be soft and hissing, or loud and vibratory, is formed in the larynx. Speech is the voice modulated in its passage through the mouth and nose by the agency of particular organs, such as the tongue, the palate, the teeth, the lips. It is conventionally only, and for the sake of convenience, that physiologists speak of a whisper as being speech without voice, that is, without vibratory voice; and of those who speak only in a whisper, as having lost their voice, in contradistinction to those unfortunates who suffer under a loss of speech, which properly constitutes dumbness.

Dumbness originates exclusively from original defect of hearing—thus indicating the intimate connexion between the gift of articulation and the perfection of that sense. Again, the capability of the dumb (deaf-mutes, as with something akin to an affectation of precision they are now often called) to acquire the use of speech, rude as it commonly is, shows how largely the organs concerned are placed under the control of the will.

The Sources of Sound.—The organs of the voice and of speech are analogous to instruments of music, so that some preliminary observations on the sources of sound become requisite.

In every case sound is derived from the vibration of a body. It is, however, erroneous to describe sound as merely a vibration of the air. Most sounds, it is true, reach the ear through the vibration of the air, whether they have had their source in the air, or in some body with which it is in contact. It is usually said, that a bell has little or no sound in a vacuum. This is in so far true; for unless a communication is made between the ear and the bell independently of the air, little or no sound would be heard. But if a cord or some similar body be stretched between the bell and the ear, and particularly if the external cavity of the ear be previously stopped with some substance, such as chewed paper, which the cord is made to touch, the sound of the bell will be distinctly heard. In such a case no part of the communication of the vibrations of the bell is made through the air—the membrane of the tympanum or drum of the ear receives the vibrations and transmits them through the chain of little bones to the labyrinth or most interior part of the ear, where, by means of undulations excited in the fluid in contact with the subdivisions of the auditory nerve, the requisite impression is made.

Many other instances may be cited of sounds produced by the vibrations of solid bodies being conveyed to the ear without the intervention of the atmosphere. For example; when a tuning-fork is made to vibrate and placed between the teeth, the sound is conveyed from the teeth, through the bones of the face and the head, to the auditory nerve. Also when a solid-vibrating body is suspended by a cord which is brought into contact with the teeth, the sound is heard independently of the atmosphere. Again, when a sounding body is suspended between two cords reaching to the ears, the influence of the air is excluded. When a cord is extended from a sounding body to some part of the head, particularly to such parts as are sparingly covered with soft substance, the sound is heard without the assistance of the atmosphere. When a watch touches the teeth, particularly of the upper jaw, its ticking is distinctly heard on the same principle. When the watch is applied to the tongue, the sound is much fainter. We find it stated that the vibrations of a metallic spoon were heard at the distance of three hundred yards by means of a cord extended to the ear. We are told that the sound of distant cavalry is heard much better when the ear is applied to the ground than when the listener stands erect. In cases of this kind, where the sound is conveyed along the surface of the ground, it is to be understood that the sounds are produced in the ground itself, or in solid bodies communicating directly with the ground.

Vibrations are also communicated from water to the ear without the assistance of the atmosphere. For example; in bathing, when the head is plunged under water, distant sounds produced in the water are heard distinctly. When, however, sounds proceed from water into air, the effect produced on the air is faint.

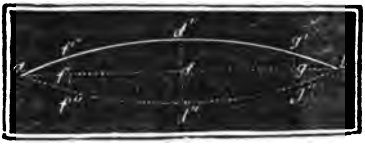
The sounds which reach the ear through the atmosphere may originate in vibrations of the air itself, or may have been communicated to it by the vibrations of liquid or of solid bodies. And this, doubtless, is the common case. Nevertheless, it is plain, from what has been above stated, that to describe sound as a vibration of the air is to view it in too limited a sense.

To produce sound the vibrations must be of a certain strength; for it is plain that a body often continues to vibrate after it has ceased to emit sound. Sounds pass through air with less rapidity than through water, and through water with less rapidity than through solid bodies. For example; the sound of a hammer struck at the top of a high house is heard double by a person standing on the ground below; that is to say, the first sound which reaches his ear is conveyed through the solid materials of the house, while the second sound is transmitted through the air to his ear. It is observed, also, that on the approach of a heavy waggon in the street the furniture of a house begins to shake before the noise of the waggon is heard.

The velocity of sound in air is estimated at 1130 feet per second—in water at 4708 feet in the same unit of time. The velocity of sound conveyed through solid bodies appears to vary much according to the texture of the substance. From some experiments, it appears to pass through deals of fir-wood at the rate of 17,400 feet per second, which is upwards of three miles.

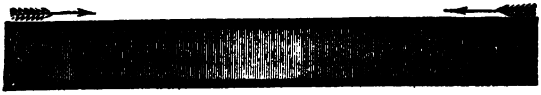
When a sound is produced in an open space, it is more short and sharp than when in a room; because, when a sound occurs in a room, the vibrations of the air which strike against the walls and furniture excite new vibrations in these bodies, which, being again communicated to the air, affect the ear in close succession with the original vibrations, and so prolong the sound. This effect is termed the reverberation of sound. When there are no bodies near at hand to reverberate the sound, but a body or bodies at a distance capable of that effect, an echo is produced. Thus an echo may be described as a reverberated sound, which does not reach the ear until the primary sound has ceased. An echo may take place from a wall, a rock, a grove of trees, and, as it is said, even from a cloud; and also, as it would seem, from condensed air. If an echo can take place from a cloud, it is an example of an echo produced by the vibrations of water in its liquid state. The body from which a distinct echo takes place must be at a considerable distance, and there must be no interposed bodies capable of keeping up the succession of vibrations. In every large and lofty empty room there is a species of imperfect echo, owing to the want of furniture to keep up the succession of reverberations between the termination of the primary sound and the reverberations from the walls and roof. The echo of a monosyllable requires a less distance than the echo of a dissyllable; it is estimated that the distance required for a monosyllable is 80 feet, that for a dissyllable 170 feet.

A musical sound is to be distinguished from a noise. A noise consists either of a single powerful concussion or report, or else of an irregular repetition of such sounds. A musical sound consists of a number of synchronous vibrations; that is, of vibrations occupying the same minute period of time. The vibrations in a musical sound are not all of the same extent; but whether great or small, each occupies the same period of time—in short, they are like the vibrations of a pendulum, which, whether great or small, are performed in the same space of time, when the pendulum is of a definite length.



Sonorous undulations may be described as of two sorts—namely, curved and molecular. We have an example of curved undulations when a string, *f d g*, fastened at both ends, *a b*, so as to be tight, is drawn to one side at its middle point. By this retraction the string, which was before straight, is now bent into a curve, *a f' d' g' b*. When let go it not only recovers its former position, but passes to the other side, assuming the same curved form, *a f'' d'' g'' b*, into which it was at first drawn; and thus it continues to vibrate from side to side, alternately forming a curve, with a gradual diminution of extent on each side of its original position. So long as these vibrations are of considerable strength, a sound is emitted; but, as before observed, the sound ceases before such a string returns entirely to rest. To produce an impression on the ear, but a moderate velocity in the vibrations is necessary. It appears that a sound may remain audible with a velocity of no more than $\frac{1}{100}$th part of an inch in a second: perhaps it may be heard even with a much smaller velocity than this. Nevertheless, in such a case it is probable that the initial velocity must be considerably greater than that here described.

What is termed molecular undulation is exemplified in the alternate condensation and rarefaction of air. When we blow into a tube open at both ends, the air contained first becomes condensed in the middle, and rarefied at the two extremities, as seen by the lighter shade in the cut; but after a while the case is reversed, the rarefaction being in the middle, the condensation at the extremities.



What is termed difference of tone depends upon the number of vibrations in a given period of time. When the number of vibrations is small, a grave sound is produced; when the vibrations are numerous in the same time, an acute sound is heard. Their thickness being equal, a long string produces fewer vibrations than a short string in a given time. Thus, by lengthening a string, the tone of a musical sound produced by its vibration passes from the acute to the grave. When the quality of a sound is spoken of, it has no reference to the number of vibrations in a given time, quality being dependent on the molecular constitution of the sounding body. From what has been already said, it must be seen that the mere extent of vibrations does not affect the tone. It appears, however, that loudness of sound is dependent chiefly on the extent of the vibrations.

Musical sounds, then, are produced either by the vibrations of solid bodies, of liquid bodies, or of aëriform bodies, or by a combination of the vibrations of two or more of these.

There are even musical instruments, or musical combinations produced by solid bodies, independently of any musical tension. For example, melody may be extracted from cylinders of glass, or of metal struck either directly or by means of keys—the tuning-fork, the gong, the cymbal, the bell, are examples of the same kind. The harmonica consists of a series of glass vessels made to yield musical sounds by the friction of the fingers. But the most important case of this kind, as bearing on the explanation of the phenomena of the voice, is the vibration of an elastic plate produced by a current of air which it continually emits and excludes. Such a plate is employed in those forms of the organ-pipe which have been termed the *vox humana pipe*, and regal pipe. The vibrations of water are hardly employed to produce musical sounds; nevertheless, the purling rill and the distant cataract plainly fall within the description of musical sounds.

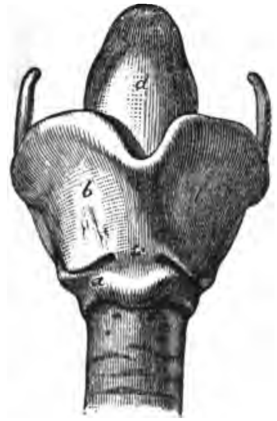
In simple wind-instruments of music, we have examples of musical sounds produced by molecular undulations of air: in the flute, the flageolet, the diapason organ-pipe, the humming-top, the cavity of the mouth in whistling, and playing on the Jew's-harp, the molecular undulations of the air are the sources of the musical sounds. In the flute and flageolet the length of the tube is altered at pleasure by opening or shutting the holes. When a hole is opened it is the same thing as if the pipe were cut off a little beyond the place of the hole.

In many musical instruments the vibrations of solid bodies co-operate with the undulation of the air to produce the musical sounds. This is the case in the trumpet and in the various kinds of horn. In these instruments, the force of the inflation produces what are termed harmonic divisions. The trombone is so contrived that the length of the tube may be altered at pleasure. In what are termed the reed pipes of an organ, there is an elastic plate which vibrates in unison with the column of air which they contain. The vibrations of animal membranes, when put on the stretch, as a source of musical sounds, are usually considered separately, both from the sounds produced by solid bodies and those produced by the molecular undulation of air. There are examples of this effect of those membranes in the use of such instruments as the drum and tambourine. These instruments are chiefly prized for their loudness. Under the same head, however, falls the membranous tongue, which bears closely on the illustration of the human voice. What is here referred to is not, indeed, a musical instrument, but a contrivance employed to exhibit the effects of sound under circumstances analogous to those of the human larynx. The most remarkable experiment of this kind is made by placing two thin plates of India rubber over the end of a tube, so as to leave a very slender fissure between their margins in the middle line, and fixing these by a ligature. Two pieces of leather employed in the same manner produce a similar result. When two such tongues or membranes are placed over the orifice of an organ-tube, and the current of air made to rise through it, vibratory motion is maintained by this current, and a considerable range of musical sounds is produced. The two tongues or membranes in this experiment should be in the same place, and the space between them should be very minute: the edges of the tongue should not be farther apart than from $\frac{1}{12}$th to $\frac{1}{10}$th of an inch. The experiment succeeds even better when the edges actually touch. To this experiment reference will be made hereafter, when we come to speak of what occurs in the human larynx during the exercise of voice.

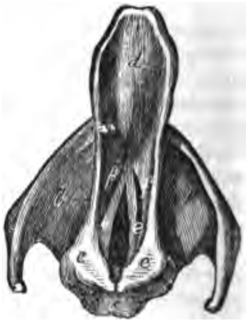
Organs of Voice and Speech in Man.—The organs concerned in voice and speech may be described as the chest and lungs, the windpipe, the larynx, the posterior cavity of the mouth, the nostrils, which communicate with that posterior cavity, the palate, the tongue, the teeth, and the lips. The sounds which constitute voice belong to the order of musical sounds, independently altogether of the singing voice. All that is properly termed voice takes place in the larynx, which is properly the instrument of voice. But even independently of the modifications by which voice is changed into articulate speech, the voice is variously affected by the other parts which have been enumerated: by the chest, as regulating the force of the air; by the windpipe, as susceptible of several degrees of length and tension; by the posterior cavity of the mouth, as offering an expanded vault; by the nostril, as affording a double passage of exit for the breath; and by the various conditions of the tongue, the palate, the teeth, the lips, according to the position in which they happen to be at the moment.

The chest and lungs together constitute, in reference to the voice, a musical bellows, capable of supplying air with more or less force to the organs of voice. The peculiarity of these bellows consists in that the air must be renewed, at short intervals, by entering from without by the same passage by which it is expelled when the voice is exercised. It can, however, supply air without interruption, in a continued stream, for about fifteen seconds. The lung consists of two large bags of air, and does not materially differ from the wind-box of an organ, or rather from the bag of a bagpipe. No air can enter the lung, or escape from it, except through the windpipe. The walls of the chest are everywhere in contact with the outer surface of the lung, and close in around the point at which the windpipe rises upwards to the larynx. The chest is capable of expansion in every direction; that is to say, by means of muscular action its walls recede from the surface of the lung, so that the cavity in which this air-bag is contained, is augmented in every direction,—in length, in breadth, in depth. Whenever this enlargement commences the air begins to enter from without. By this process, in two or three seconds, many cubic inches of air can be drawn into the lungs.

So nice is the action of the muscles, by which the chest is again contracted in size, and the lung is compressed, that the stream of air which shall issue in a given period through the larynx, by the influence of the will, is under the most complete control. The prominence of the larynx on the fore part of the neck is popularly known by the name of Adam's apple, by which, probably, its remarkably greater prominence in the male than in the female is referred to. The long succession of minute tubes, by the gradual union of which the other trunks, and finally the windpipe, are formed, has this peculiarity, that the aggregate of the areas of the smaller tubes greatly exceeds the area of the trunks which they combine to form. From the windpipe throughout, almost to their origin in the minute cells, the tubes are provided with tense walls, by means of the cartilaginous appendages before referred to; in the windpipe itself these cartilages assuming a more definite form. They are in complete rings of cartilage, being deficient posteriorly; that is, each ring of the windpipe traverses about two-thirds of its circumference, leaving the remaining one-third, on its posterior aspect, destitute of this support. The number of rings in the windpipe is from fifteen to twenty; in other respects the tube is chiefly membranous, yet provided with muscular fibres capable of diminishing its calibre, by drawing together the extremities of the rings. It has been proved, by sufficient experiments, that when the larynx is raised by the powerful muscles attached to it, the windpipe is drawn up from the chest in a corresponding extent, and that at the same time its diameter is diminished by about one-third.



a, basement or cricoid cartilage resting on the cylindrical windpipe; *b*, protecting cartilage or thyroid cartilage; *d*, valve-like cartilage or epiglottis.

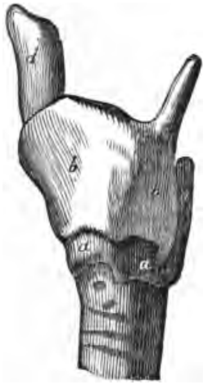


c c, Pyramidal or arytenoid cartilages; *a*, cricoid or basement cartilage; *e e*, the tongues or proper vocal cords, called also vocal ligaments, also aryteno-theroid ligaments and inferior vocal ligaments; *f f*, the ventricles of the larynx; *d*, the epyglottis.

The base, or lowest part of the larynx, rests on the upper part of the windpipe, and this base consists of a ring, somewhat more developed than any of the rings of the windpipe, yet not so different from these but that it might be regarded as the summit of that tube. This ring differs from the rings of the windpipe in being complete all round; it is not, however, of a uniform breadth in the direction of from below upwards, being broader at the posterior part. It may be likened, then, to a ring, with a stone or a seal, the expansion behind corresponding to the stone or seal. On the upper edge of the expanded portion of this ring, at the base of the larynx, are set two slender bodies of a pyramidal form, which bear the most important part in the mechanism of the larynx as an organ of voice. These two bodies are exactly alike, and are placed almost close together, like two miniature obelisks set on end. The connection of their inferior extremities with the basement ring of the larynx, is by articulation, viz. by a true joint, like the shoulder-joint; that is to say, they are movable on the cartilaginous ring which supports them. From the one to the other, on their posterior aspect, muscular fibres extend, by the contraction of which these two minute pyramids are made to approximate together. From the fore part of each, near their bases, an elastic substance proceeds forwards, converging, to interlace with its fellow at the anterior part of the larynx; that is to say, a minute somewhat triangular space is formed by two portions of elastic tissue, which cross the basement ring of the larynx from behind forwards, the base of this triangle being the space between the two pyramidal bodies just spoken of and its apex behind, a portion of the larynx to be presently alluded to. This triangular space between these two portions of tissue, vocal ligaments, as they are called, is the aperture by which the breath enters and issues in respiration, and by which, when contracted to a narrow chink, the air is forced through in the exercise of voice. These, then, are the most essential parts of the larynx; the two pyramidal bodies each resting on the posterior part of the basement ring, while the two ligaments proceed forwards, each from the base of one of these pyramids, to form a triangle, the apex of which is so directed as to be over the anterior part of the aperture of that basement ring. It is manifest that when these two minute pyramids are drawn close together by the action of the muscular fibres, the base of the triangular opening is diminished, so that the posterior or wider part of the opening becomes obliterated; also, if the apex of this triangle be drawn forwards, that the sides formed by the two vocal ligaments will still further approximate. Such, then, are the two actions by which the triangular aperture is reduced to a minute chink, namely, by the points to which its base is attached being made to approximate, and its apex being drawn forwards.

Other muscular fibres are so disposed as to antagonise the forces which close the aperture; two sets of fibres on each side extend from the basement ring inwards, to be attached to the pyramidal cartilages, by which they are drawn asunder, and the base of their rectangular aperture again restored to its former extent.

Several important, yet less essential parts of the larynx, remain to be described. The anterior narrow part of the basement ring supports that great prominence which constitutes Adam's apple. This is by far the largest portion of the larynx, but may be regarded merely as a defensive plate guarding the essential parts of the organ from injury. When the finger is placed upon its upper margin, and directed a little upwards, a hard, wire-like circle is felt; this is the convexity of the hyoid bone, or bone of the tongue, which has intimate connections, by ligaments and muscular fibres, with many adjacent parts, so that it is rendered, as it were, a centre of motion. Hence, when the hyoid bone is raised, many of the adjacent parts follow its movements. The hyoid bone is described as having the shape of the Greek upsilon, the convexity being directed forwards, and to be felt immediately above the great cartilage of the larynx. This great cartilage, then, termed the thyroid cartilage, may be described as a quadrilateral sheet of cartilage, with appendages at its four angles, named its cornua, or horns. This quadrilateral sheet is bent along its perpendicular middle line, and this bending constitutes the angle which is felt in Adam's apple: the upper horns are attached to the hyoid bone, the under horns to the basement ring before spoken of. Thus the thyroid cartilage is wrapped round the essential parts of the larynx, in front covering them in, leaving them exposed behind. The prominent angle in front corresponds to an interior angle on its posterior aspect; and to the middle part of this interior angle extends the apex of the triangle formed by the vocal ligaments, and there obtains an attachment.



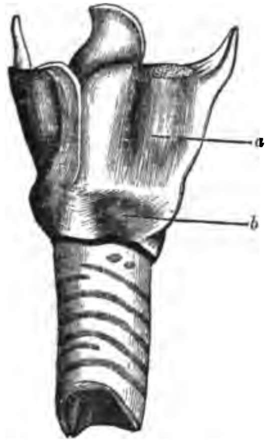
a, the cricoid; *b*, the thyroid; *d*, the epiglottis.

A movable valve, like a little tongue, its apex directed backwards, is attached to the same interior angle of the protecting cartilage, a little higher up, overhanging the cavity of the larynx. Between the same interior angle of the anterior protecting cartilage, and the two movable posterior cartilages before described, muscular fibres proceed, by the contraction of which those triangular movable cartilages are drawn forwards, so as to relax the elastic cords, already termed vocal ligaments. From the same interior angle of the protecting cartilage, an elastic substance proceeds, radiating in different directions, so as to close in the parts otherwise unoccupied above the lateral portions of the basement ring of the larynx. This elastic substance, in particular, forms two cords, extending between the superior points of the movable triangular cartilages and the sides of the tongue-like valve before spoken of. These cords constitute what have been termed, somewhat improperly, the superior vocal ligaments. When the space beneath these so-called superior vocal ligaments and the true vocal cords, or vocal ligaments, is examined, a cavity is found on each side of considerable extent; and the two cavities are called the ventricles of the larynx. The mucous membrane, descending from the mouth and nostrils, covers and forms a lining to these parts in its passage downwards into the windpipe and lungs; so that the so-called superior ligaments of the larynx are often described as mere folds of the mucous membrane, extending between the posterior pyramidal cartilages and the protecting cartilage. It appears, however, from more minute investigation, that these folds of the mucous membrane do actually contain an elastic substance, not less capable, under certain circumstances, of vibratory action than the true vocal cords, or true vocal ligaments.

To recapitulate, then, the prominent points in the conformation of the larynx—the windpipe, called by anatomists the trachea, is surmounted by a complete cartilaginous ring, about an inch in diameter. This ring is the only outlet of the lungs by which air can issue from their numerous cavities, and is the only inlet by which air can penetrate from the atmosphere into the same cavities. This ring, being of a firm cartilaginous structure, is plainly incapable, under any ordinary circumstances, of dilatation and contraction. But the air is permitted neither to pass inwards, nor to come forth through the whole area of this cartilaginous ring, whether in respiration or in the exercise of voice. Its area is closed up on each side by impervious texture, so as to permit a passage to the air only by a chink, variable in its size, extending in the direction of its antero-posterior diameter. This chink is bounded, according to the common descriptions, by the vocal ligaments. It is more accurate to say that this chink is bounded in its anterior part by the vocal ligaments, one on each side, and at its posterior part by the cartilaginous processes of the base of the movable pyramidal cartilages to which these cords are connected. This chink, when most expanded lengthways, is about eleven lines in length, and of this space seven lines lie between the vocal ligaments, and four between the opposite cartilaginous bases of the pyramidal cartilages, above spoken of, to which anatomists give the name of arytenoid. This chink, as above stated, is usually described as triangular, with its base between the two arytenoid cartilages, and its apex attached to the anterior angle of the protecting cartilage, above spoken of, to which anatomists give the name of thyroid. More correctly, at its greatest dilatation, it has a lozenge shape, with the posterior angle truncated. Thus the chink commences narrow immediately behind the thyroid cartilage, expands between the vocal ligaments to their attachment at the base of the arytenoid cartilages, and then contracts in the space between the cartilaginous bases of these two bodies, not to a point, but to a truncated angle. The widest part of the chink, in its greatest state of dilatation, is about five lines and a half—nearly half an inch. This greatest degree of dilatation takes place during inspiration; during expiration, the chink undergoes a slight contraction. But during the exercise of voice, the posterior part, bounded by cartilaginous margins, as being between the base of the arytenoid cartilages, is entirely obliterated. Thus it is correctly stated, that the chink, concerned in the exercise of voice between the true vocal ligaments, at its greatest dilatation, is of a triangular shape, being entirely bounded on the sides by the vocal ligaments, and its base corresponding to the points between their attachment to the arytenoid cartilages. As before stated, the arytenoid cartilages are attached to the upper surface of the posterior part of the basement cartilage of the larynx, or cricoid cartilage; and the vocal ligaments being attached to the bases of these arytenoid cartilages, it is manifest, that when these cartilages are drawn together, the vocal cords must approximate; that when these cartilages are drawn asunder, the vocal cords must recede from each other at their posterior part; that when the arytenoid cartilages are drawn backwards, the vocal cords must be put on the stretch; that when the thyroid cartilage, to the interior of which the apex of the triangle, formed with the cords, is attached, is drawn forwards, they must also be put on the stretch. All these changes are known to occur by the action of particular sets of muscles. The thyroid cartilage, which forms "Adam's apple," is connected to the basement, or cricoid cartilage, by an elastic membrane, which of itself tends to keep the thyroid cartilage nearly in the same perpendicular line with the cricoid, so as, in some degree, to stretch the vocal ligaments. But there are two muscles extending between the cricoid cartilage and the thyroid, by which the thyroid cartilage is drawn forwards, so as distinctly to stretch the vocal ligaments. There are also two muscles extending between the posterior part of the cricoid cartilage and the posterior surface of the arytenoid, by which the arytenoid cartilages are drawn back. These two pairs of muscles, when they act concurrently, must very much stretch the vocal ligaments. A set of muscular fibres, before spoken of, passing between the arytenoid cartilages on their posterior aspect, by their contraction causes the cartilages to approximate. Two other muscles, extending from the sides of the cricoid cartilage to the arytenoid, draw them asunder. Some other muscular fibres are found connecting the cartilages of the larynx; but the account of these, owing to their less importance, may be omitted.

The small muscles of the larynx are represented in the annexed figures (page 124). The crico-thyroidei (*b*, fig. 1, *a*, fig. 2), and the crico-arytenoidei postici (*b*, fig. 2), extend the vocal cords in the direction of their length, and, at the same time, narrow the glottis. The crico-arytenoidei laterales (*c*, fig. 2), and the thyro-arytenoidei (*d*, fig. 2), rather relax the vocal cords. The oblique and transverse fibres of the arytenoideus (*e* and *f g*, fig. 2) close the posterior half of the glottis. The epiglottis (*K*, fig. 2) forms

a valve, which can be brought over the glottis by fine muscular fibres attached at *b* and *i* (fig. 2).



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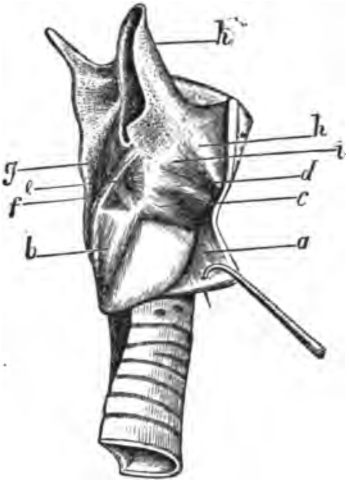


2.

Such, then, are the parts of the larynx which must be explained to render the phenomena of voice intelligible.

The larynx, like other organs of the body, is largely supplied with blood by the common blood-vessels. Two nerves on each side are devoted to the actions of the larynx. These nerves are from the eighth cerebral pair: the superior laryngeal nerve is expended chiefly on the mucous lining of the larynx; the inferior laryngeal nerve, derived from the recurrent of the eighth pair, sends minute filaments to the several muscles concerned in the movements of the larynx.

Besides the movements of the component cartilages of the larynx on each other, attention must be paid to the motion of the whole larynx upwards and downwards. This motion takes place constantly in the act of deglutition, but also on many occasions when the voice is exercised, particularly in singing. When the whole larynx is raised, the windpipe is drawn proportionately upwards from the chest, and so put on the stretch. This movement has unquestionably some effect in extending the compass of the voice. It was before stated that the hyoid bone is connected to the protecting cartilage of the larynx, and that when this bone is drawn upwards, the larynx is drawn upwards along with it. The hyoid bone is drawn upward by muscles attached in particular to the lower jaw, and also to the temporal bone of the skull. The hyoid bone is drawn downwards by muscles attached to the superior part of the breast-bone and to the shoulder-blade. From the upper part of the breast-bone a pair of muscles ascends, to be attached to the thyroid cartilage of the larynx, and a pair of muscles also extends between the thyroid cartilage and the hyoid bone. Thus ample provision is made for the movement of the whole larynx in concert with the movements of the hyoid bone.

A few words must next be devoted to the cavities through which the air passes out-

wards after issuing from the larynx. Behind the larynx is the cavity of the pharynx, situated in front of the cervical vertebræ, and ascending to the inferior aspect of the base of the skull. This cavity, not improperly termed the posterior cavity of the mouth, communicates with the nostril above, and on either side, by a narrow canal, called the "Eustachian tube," with the cavity of the drum of the ear. This posterior cavity of the mouth is divided from the anterior cavity by the veil of the palate, a musculo-membranous movable curtain, which by its motions more or less completely divides the anterior from the posterior cavity of the mouth. The movable, tongue-like valve, before spoken of, termed by anatomists the epiglottis, overhangs the orifice of the larynx; the arches of the palate descend on either side, possessed of a muscular character. From the union of these above the uvula hangs down. The tongue, free and movable in its anterior part, forms the floor of the whole passage between the root of the epiglottis and the incisor teeth of the lower jaw. The muscular mass forming the cheeks contracts the cavity of the mouth on the sides, and the lips by their mobility variously modify the aperture by which the air issues.

Thus the air issuing from the larynx may pass out either by the nostrils or the mouth. It passes out by the nostrils when the mouth is closed, or even when the veil of the palate descends. When the veil of the palate is raised, and the mouth is opened, a free passage is afforded, through what has been called the oral canal, outwards. The oral canal is manifestly capable of much greater modification as to size, than the passage of the nostrils.

> "The tongue, the lips, articulate; the throat,
> With soft vibration, modulates the note."—DARWIN.

On the Human Voice.—In the investigation of the human voice, two points in particular deserve attention—first, the inquiry into the precise seat of the sounds; and secondly, into the mode in which these sounds are produced.

As to the first question, it is now determined, beyond all doubt, that the sound of the voice is generated in the glottis, and neither above nor below that point. Before going further, it should be remarked that this word glottis has not always been used in exactly the same sense. "By turns," says the eminent French physiologist, Adelon, "the superior aperture of the larynx, its inferior aperture, and the intermediate space between these two apertures, has borne the name of glottis; but, according to the etymology of the word, derived from γλοσσα, the tongue, the speech, no other part of the larynx should be called by that name but that where the vocal sound is formed—and we shall see that that part is the inferior aperture or chink."—*Physiologie de L'Homme*, ii. 256. In this sense alone, then, the word glottis is here employed, namely, to signify the aperture between the two vocal ligaments, that is, between the two inferior vocal cords, as they are sometimes called.

Among the proofs that this chink, or glottis, is the seat of voice, it may be mentioned, that if an aperture exist in the windpipe, the sound of the voice ceases. Such an aperture is frequently formed in man as a surgical operation, and an opening has often been made in the same situation in animals for the purpose of experiment. Also, when an opening exists above the glottis, that the voice is not lost. Again, that though the epiglottis, the superior vocal ligaments of the larynx, and the upper part of the arytenoid cartilages, be injured, the voice is not lost: moreover, that in living animals, when the glottis is laid bare, it is seen that the inferior ligaments of the larynx which form the boundaries of the fissure termed glottis, are thrown into vibration: it is known, too, that the division of the laryngeal nerves supplying the muscles, which regulate the states of the aperture, and make the vocal cords tense, destroys the power of producing vocal sounds. It is also found that sounds can be produced in the dead human body by forcing a current of air from the windpipe through the larynx, provided the vocal cords be in some degree tense and the glottis be narrow. The larynx has been cut from the body, and freed from all the parts in front of the glottis; thus, the epiglottis, the upper vocal ligaments, and the ventricles of the larynx between the superior and inferior, or vocal ligaments, the greater part of the arytenoid cartilages, namely, their upper part, may be removed—in short, if nothing remain but the inferior ligaments or vocal cords, and these be so approximated that the glottis shall be narrow, clear tones will be produced by forcing air through it from the windpipe.

Such facts as these entitle us to regard the glottis and the vocal cords, which form its immediate boundaries, as the essential source of voice, while the windpipe simply conveys air, and the cavities above the glottis, comprehending the upper part of the larynx and the air passages through the mouth and nostrils, correspond to the tube of a musical instrument, by which the sound is modified but not generated.

It has been already remarked that the vocal ligaments are composed of elastic tissue, and that it is owing to this elasticity that they are adapted to the office which they perform. While, then, it is quite certain that no proper vocal sounds can be produced, except in the glottis, it seems manifest that the adjacent somewhat abundant tissue of the same kind is susceptible of a vibration and resonance in unison, so as at least to modify the sounds of the voice.

In reference to the second question—what is the nature of the change produced in the glottis during the formation of voice—no inconsiderable difficulty is met with. The points of debate which have arisen on this subject are, whether the vocal ligaments be a set of membranous cords obeying the laws of musical strings; if the aperture of the glottis be a reeded instrument, in which the vocal ligaments play the part of vibrating tongues; or even whether the real source of the sounds of the voice be not a molecular vibration of the air, produced by its passage through the narrow aperture of the glottis; and, lastly, whether the organ of the voice does not in part combine all these three sources of sound, so as to be at once, in some respects, a stringed instrument, a tongued instrument, and a simple wind instrument.

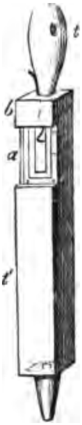
The ancients regarded the sounds of the voice as analogous to those of a flute. According to this view, the vibrations of the larynx are of little account, the actual sounds being produced by a molecular undulation of the air. That the organ of voice is not, in some degree, analogous to this kind of musical instrument, is not to be absolutely denied, but it is certain that this is not the principal mode in which the sounds are produced.

One of the earliest ideas of modern times on the subject of the voice is, that the larynx is analogous to a horn; that is to say, to a wind instrument, in which the vocal cords act the same part as the lips of the performer on a horn. Not much more than a hundred years ago arose the idea that the larynx is a set of musical cords—namely, that the vibrations of these cords, on the same principle as a stringed instrument, produce the sound, which was then conveyed outwards by the air.

The prevailing opinion of the present day is, that the larynx is a wind instrument, but a reeded wind instrument.

This common view may be expressed as follows:—the expired air is thrown into the larynx through the windpipe by the muscular action of the chest; the proper muscles of the larynx being contracted, create a sufficient tension of the vocal cords to permit them to be thrown into vibration by the impulse of the air. The sound so produced is conveyed through the mouth and nasal passages, undergoing various modifications in its passage outwards.

Let us consider, then, in the first place, what evidence there is that the organ of the voice is a reeded instrument, with a double membranous tongue.



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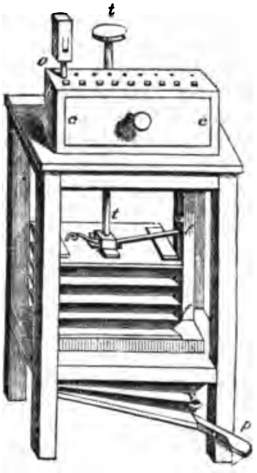


2.

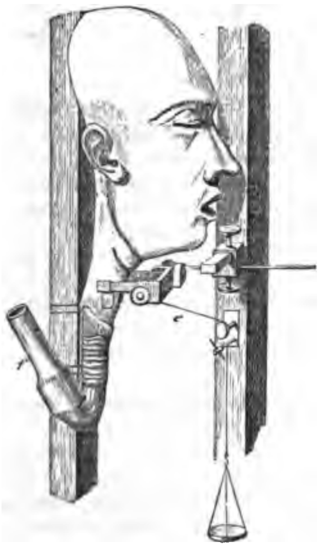
In short, the action of the organ of voice may be best explained in general terms, by comparing it with the pipe of an organ. Let us suppose *t* (Fig. 1), to be the wind-tube, into which the air is driven from below; *b*, the stopper, in which is placed the tongue; *a*, and *t*, the body-tube; and let there be a pipe, *o* (Fig. 2), to the wind-box, *cc*, and the air be driven from the bellows, *ffp*, through *t*. The air throws the tongue, *a* (Fig. 1), into a state of vibration, and passes out in undulating movements from the body-tube. Such is a general view of the nature of voice.

An experiment has been before referred to, which illustrates the effect of an elastic organic tissue, like that of the vocal ligaments, in producing sound on the principle of a double tongue. The extremity of a tube is closed by two bands of moist elastic tissue, for example, arterial tissue, so applied as to cover the whole end of the tube, with the exception of a slight fissure between the bands. In the experiments before referred to, India-rubber, or leather, was mentioned as being employed for this purpose. Both these substances produce a similar effect, but it appears that the middle arterial coat, being composed of the same tissue as the vocal ligaments, and having the same physical properties, forms the best kind of artificial larynx. When this tube is blown through at the free extremity, the tongues not only vibrate readily, but produce a range of musical tones. To obtain a pure quality of tone, it is necessary that the two membranous bands should be of equal weight and breadth, and subject to equal tension, otherwise they cannot vibrate equally in equal parts of time.

If the human larynx be dissected out, and the vocal cords be stretched, they will vibrate like a piece of artificial tissue, such as India-rubber or leather, in a current of air. In conducting these experiments, the same conditions must be secured as are required in the experiment with the tube, and the two membranous laminæ, before referred to. For example, the inner edges of the glottis, that is to say, of the vocal ligaments, must be turned outwards towards each other, so that they shall be in the same plane and parallel to each other, otherwise they will not produce any sound. Hence it may be inferred, that when the tension of the vocal ligaments takes place in the living animal, they turn upon their axis, till their planes, which, in the state of relaxation, are inclined to the axis of the vocal tube, become perpendicular to it, and as the edges of the glottis approximate, its chink is nearly or entirely closed, and they acquire the true vibrating position. The production of the most simple tones of the voice requires the associated action of a most extensive range of organs; for it is calculated that in the ordinary modulation of the voice, more than one hundred muscles are brought into action at the same time.

As the air rushes upwards from the windpipe, a portion of each edge of the glottis yields to its pressure, and is curved upwards, so as to form an angle with the axis of the vocal tube, and leave between the two edges a narrow aperture, through which the air escapes. The tension and elasticity of the vocal ligaments tend to restore them to the plane of their former position. The air having been rarefied below the glottis during their elevation, becomes dense from their depression, and the necessary force being again accumulated, they are re-elevated, and thus an oscillating movement, consisting of an opening and closing of the glottis, takes place, which being communicated to the contiguous air, the sounds of the voice are produced.

The vibrating edge of the glottis varies in length according to the pressure of the column of air in the windpipe, and the resistance of the vocal ligaments. When other circumstances are alike, the intensity of the voice is determined by the pressure of the column of air in the windpipe, and the range of movement described by the vibrating edges of the glottis. The pitch of the voice does not depend solely on the tension of the vocal ligaments, but jointly on the variations which they undergo in length and tension. Magendie observed, in the larynx of a dog, that a longer portion of the vocal ligaments vibrated while grave tones were produced, and that a diminution of length accompanied the succession of acute tones. Mayo has described the movements of the glottis in a man who had attempted to destroy himself by cutting his throat. The larynx in this case was cut through just above the vocal cords, and, owing to the oblique direction of the wound, an injury of the arytenoid cartilage and of the vocal cord on one side had occurred. When respiration was going on, the glottis was seen to be of a triangular form, but when the voice was exerted, the vocal cords passed into a parallel direction, and the glottis itself had a linear form. The posterior part of the aperture appeared to remain unclosed.



The cut represents the prepared head of a corpse, after Müller. A thread *e*, which passes over a roller to a scale, is so applied to the larynx that the tension of the vocal cords can be increased by placing a greater weight on the scale. The action of the muscles is thereby imitated. The compressing apparatus seen on the wood-cut brings the vocal cords nearer to each other, and thus produces the requisite diminution in the width of the vocal fissure. The tube *f* serves to convey the wind, which throws the tongue-apparatus into action.

And thus, if we use the human head, or the head of the dog, or of the pig, or of any other animal, we can imitate the voice of man, the bark of the dog, the grunt of the pig, &c.

Membranous tongues, like those in the larynx, differ widely from a metal tongue, shutting up the aperture, and necessarily opening and closing as the air issues.

Objections have been taken to the view which represents the voice as the result of sounds produced by membranous tongues set in motion by air, 1st, That the vibration of tongues consists in the periodical opening and shutting of the orifice through which the stream of air passes, this not being the case in the glottis; 2nd, That had it the structure of a reed, the edges of the vocal ligaments which open the chink would be alternately separated by the column of air in the larynx, and drawn together by their tension, while it has been found by experiment that air transmitted through the glottis gives rise to sound, notwithstanding that its edges are from one-sixth to one-fourth of an inch asunder In these objections, however, there is a mistake as to the essential principel of reeds—for those of the clarionet, bassoon, hautboy, &c., fail to close entirely the passages through which the breath escapes; and the case is not otherwise with the natural reed, which the lips of players on the flute and horn represent. In short, a sound can be produced by a tongue apart from the surrounding framework, indicating, beyond doubt, that so much importance should not be ascribed to the usual mode of forming reeded and tongued instruments, and to the circumstance of the air passing between the tongue and its frame. It has been shown that the law by which the variation in the notes yielded by the tongue of a mouthpiece or reed is regulated, is the same when the tongue is made to vibrate by a current of air, as when it is thrown into vibrations by being struck or inflected. By the same law are regulated the vibrations of vibrating rods; the frequency of the vibrations of two rods of the same texture and thickness being in the inverse ratio of the squares of their length. The note afforded by a reed without a tube is of the same pitch, whether it be the result of a current of air, or be produced by striking the tongue. The strength of the blast does not, for the most part, determine the pitch or sharpness of the note; but when the force of the blowing is increased, the strength of the tones is augmented. The size of the fissure between the tongue and the frame within which it vibrates, is of little consequence; when the opening is large there is a greater difficulty in obtaining the tone, but its pitch is not altered.

Some slight difficulties may still exist in the explanation of the theory of the voice as considered to be chiefly the result of a double vibrating tongue; but, altogether, as close a resemblance has been proved to exist between that kind of artificial musical arrangement and the structure of the living larynx, as can reasonably be expected in such a case.

It was already hinted that the vocal ligaments may possibly act not only as vibrating tongues in the production of voice, but also on the principle of musical strings. On this point a few words must be added. It may seem at first sight that the remark of so distinguished a philosopher as Biot, when he says, "What is there in the larynx that resembles a vibrating string? Where is the space for such a string of sufficient length to yield the lower notes of the voice? How could sounds, of the compass which the human voice represents, be produced by a string which the larynx would contain?" would suffice altogether to set aside the idea of the vocal cords acting as musical strings. But Biot here seems to have fallen into error. Deep notes are still produced by a string greatly shortened, if it retain, after a sufficient amount of relaxation, the elasticity required for vibration. His attention does not seem to have been drawn sufficiently to the nature of organic membranes, strips of India rubber and elastic animal membranes still retaining enough of elasticity for this purpose, after being much relaxed. There is, therefore, a perfect agreement between the vocal cords and vibrating strings, though their vibrations, whether as strings or as tongues, are produced not by the direct impulse of a solid body, but by the momentum of air. When the ordinary principles to which musical strings are subject are applied to the vocal ligaments, there is found to be a very close agreement, if allowance is made for the peculiarities of elastic animal substances as respects elasticity and the like.

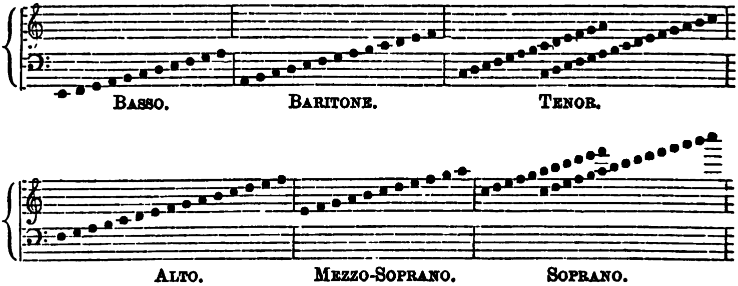
In their ordinary state, the vocal cords must be regarded as subject to a considerable tension, which, however, admits of being diminished, so as to add to the range of the lower notes. At the ordinary pitch of the voice, the glottis may be regarded as partially closed, and becoming more open as graver tones are produced; this opening of the glottis coinciding with the relaxation of the vocal cords, a double cause is afforded of the lowering of tone. When higher notes are uttered the glottis closes, assuming more of a linear form, while, at the same time, the vocal ligaments, though elongated, are thrown into a much higher state of tension. In the words, then, of Mr. Bishop, "since the vocal ligaments have been proved to extend and contract for acute and grave sounds respectively, and after death vibrate in a great measure like musical strings, we think it may be fairly inferred that they likewise obey, to a certain extent, during life, the laws of the vibrations of such strings." * * * * "It is moreover observable, that the extension and relaxation of the vocal cord, which, as we have seen, are analogous to those of a musical string, produce a corresponding shortening and elongation of its axis, regarded as a tongue; and, lastly, since one tone only is produced at a time, the vibrations resulting from the double action which appears to exist in the vocal apparatus must be synchronous." * * * * "It might possibly be objected to the idea of this two-fold action, that the production of sound by the vocal cords is sufficiently accounted for by supposing them to vibrate merely as elastic tongues; but then it is found by experiment, that by artificially dividing their length into two ventral segments, there results the octave of the fundamental note, which proves that at all events they vibrate as cords. In conclusion, we must bear in mind the vast difference between natural and artificial mechanism, and however complicated a problem it may be to determine that constitution of the vocal apparatus, by which the thyro-arytenoid ligaments may simultaneously obey the laws of cords and tongues, yet to a physiologist who is accustomed to meet with the most admirable contrivances and combinations in the animal frame, the difficulty of finding a strictly mathematical solution is, in such a case, no objection to its truth, when the facts, as far as they have been observed, are decidedly favourable to its reality."—*Cyclopædia of Physiology, article Voice*, p. 1481.

It was before hinted at, that the vibrations of the walls of the tubes through which the voice is conducted may, in some degree, influence its sound. In rigid tubes, the vibrations depend on the nature of the impulse propagated in the air within, jointly with the length of the pipe. So long, then, as the length of the pipe remains the same, and no change takes place on the material of its walls, the pitch of the sound produced by the undulations of the air within, remains unaffected. The dimensions of the windpipe, such as its length and diameter, are invariable; and, were the height of the larynx, and the dimensions of the bifid tube (the nose and mouth) through which the air issues after the formation of voice, equally invariable, the vibrations of these parts would produce no change on the pitch of the voice, the quantities being constant for each tone produced in the glottis. It has been found that, by taking tubes composed of layers of paper, of constant length, but varied in thickness, graver sounds were produced as the parietes became thinner, and that the gravity of the sound was increased by moistening and relaxing the sides of the tubes. It was before noticed, that the windpipe is capable of being drawn upwards from the chest to a small extent, while the larynx is elevated, and that this tube admits of being diminished in its diameter by about one-third part. Moreover, the pharynx, the mouth, and the nasal cavities are also susceptible of various modifications of diameter, so that the pipe, so to speak, near the middle of which the vocal sound is produced, is in a very different condition from a rigid tube. Hence, it has been concluded that provision is made for an invariable adaptation between the amount of tension, the vibrating length of the vocal ligaments, and the walls of the vocal tube, for the production of the ordinary tones of the voice. It appears, indeed, to have been proved that the vocal tube is so short, that were it rigid, it could not influence the pitch of the note which the glottis originates. But its want of length is compensated for by the relaxation of its walls, so that it comes to vibrate synchronously, and so to give forth sounds equally grave with those of the glottis. Its effect, therefore, is to add to the force of the tone, which, without its aid, would have been found to possess less intensity.

After considering this subject in every possible light, the conclusion appears to be that to which Mr. Bishop has come, namely, that the evidence shows "the vocal apparatus to be influenced by the air expelled from the chest, in precisely the same way as if it were a stretched cord, a reed, or a vibrating tube. Why, then," he continues, "should we hesitate to adopt the obvious conclusion that the vocal organs do, in fact, combine the properties of these various instruments, and are thus the perfect types of which these instruments are only imperfect imitations?"

Singing.—The notes of the human voice are capable of being produced in three separate kinds of sequence. In ordinary speaking, the successive notes have nearly all the same pitch. This kind of succession, then, is properly termed the monotonous. Some deviation from this monotony occasionally arises, as when certain syllables receive a higher intonation for the sake of accent, and when, in reading or reciting poetry, rhythm is added to the accent. In these cases, however, the deviation from monotony of pitch is too slight to require a separate head. In the expression of passion, accompanied by vehement exercise of the voice, there is heard a sudden transition from high to low notes, or the reverse. This, then, constitutes the second kind of sequence in the notes of the human voice. Musical notes constitute the third mode of sequence. In music the sound has the requisite number of vibrations, and as the sounds succeed each other they exhibit that relative proportion in the number of vibrations which jointly characterize the notes of the musical scale. Of the adaptation of one sound to succeed another, so as to preserve the musical character of the succession, the human ear is the only original standard.

Compass of the Voice.—In singers the compass of the voice extends through two or three octaves. When the male and female voices are taken together, the entire scale of the human voice includes four octaves. The lowest note of the female voice is about an octave higher than the lowest of the male voice; the highest of the female voice is about an octave higher than the highest of the male. The first four notes of all voices are most commonly weak. There are two kinds of male voice, the bass and tenor; and two kinds of female voice, the contralto, and soprano. The essential distinction between these voices does not consist in their difference of pitch. The bass voice commonly reaches lower than the tenor, and its strength lies in the low notes; while the tenor voice extends higher than the bass. The contralto voice has most commonly lower notes than the soprano, and is strongest in the lower notes of the female voice; while the soprano voice reaches higher in the scale. It is found, however, that bass singers can sometimes go very high, and the contralto not unfrequently sings the high notes like soprano singers. The difference between the bass and tenor voice, and between the contralto and soprano, is plainly, then, not one of pitch, but consists in the peculiar timbre or quality of the notes—for these several voices are distinguished from each other even when sounding the same note. The qualities of the baritone and mezzo-soprano voices are less marked; the baritone being intermediate between the bass and tenor, the mezzo-soprano between the alto and soprano.



The difference of pitch between the male and female voice is connected with the different length of the vocal ligaments in the two sexes. It appears that the lengths of the male and female vocal cords in repose are nearly as 7 to 5, and in tension as 3 to 2; in boys at the age of fourteen the length is to that of females, after puberty, as 6·25 to 7,—so that the pitch of the voice is nearly the same. The difference in the quality of the female voice, as compared with that of the male, is owing to the considerable difference presented by the two sexes in the walls of the larynx; the male larynx being much more expanded, and forming a much more acute angle in front. It is not yet clearly understood what is the cause of the different qualities of voice, as exhibited in the tenor and bass, and the contralto and soprano. As Müller remarks: "We may form an idea of the cause of these differences of timbre, from recollecting that musical instruments made of different materials, as metallic and gut-strings, metallic, wooden, and membranous tongues, metallic, wooden, and paper pipes, or flutes, may be tuned to the same note, but that each will give it with a peculiar quality or timbre."

In short, when the variations of the larynx in different individuals of both sexes, and at different ages, under the various circumstances more or less favourable to the development of the respiratory organs, are considered, as well as the remarkable fact that every human being is characterized by a speaking voice peculiar to himself, we shall be at no loss to understand why the singing voice should vary in different persons, not only in pitch, but also in quality.

The voice termed falsetto has much engaged the attention of physiologists. Most singers, particularly males, besides their natural voice falling under one or other of the before-mentioned characters, have the power of producing a double series of notes, of a different description. To the second series of notes the name of falsetto is applied. The notes of the natural voice—called also chest-notes—are fuller, and distinctly indicate a stronger vibration and resonance, while the falsetto voice has more of a humming character. It is only with the natural voice that the deep notes can be produced, while the highest notes of a male voice are falsetto. The notes belonging to a middle pitch may belong either to the natural or the falsetto voice. Thus the two registers, as they are termed, of the voice are not bounded in such a manner that the one ends where the other begins, as, through a certain compass, they run side by side. It is remarked that the bass voice becomes falsetto lower in the scale than the tenor. In the female voice there is less seldom presented a very marked distinction between the natural and falsetto registers.

In a human larynx detached from the body two distinct series of tones can be produced, when the tension of the vocal cords is very slight. One of these series corresponds to the tones of the ordinary voice, the other to the tones of the falsetto voice. With a certain degree of tension of the vocal cords both these kinds of tones may be produced; sometimes the one kind, sometimes the other, being heard. With a different kind of tension of the cords, notes of the falsetto character are constantly produced, whether the current of air passing through the glottis be forcible or feeble. If the vocal ligaments be much relaxed, the sounds of the ordinary voice always result, whether the current be feeble or forcible. When a slight tension of the ligaments is kept up, the falsetto is most easily produced by blowing very gently; while if the blowing be more energetic, the sound belongs to the ordinary voice. Thus, two different notes may be produced, under the same degree of tension of the ligaments, by a different force in the blowing; and the distance of these two notes from each other may be as much as an octave. "The real cause," says Müller, "of the difference between the falsetto and the notes of the natural voice is, that for the former the thin aperture only of the lips of the glottis vibrates, while for the latter the whole breadth of the cords are thrown into strong vibrations, which traverse a larger sphere." The peculiarities of the voice in different individuals must be chiefly dependent on the particular form of their air-passages and of the lining membranes, and the consequent differences in their mode of resonance. That such causes are adequate to produce all the varieties of the voice in individuals, appears from the circumstance that many persons, by altering the form of their vocal organs, can imitate the various tones of the voices of other individuals.

The nasal quality of the voice is determined by like causes. This nasal tone appears to be given to the voice in two ways; thus a nasal sound is produced, though the external openings of the nostrils be closed when the arches of the palate approach each other, and the larynx ascends higher than in the natural voice. When the nostrils are obstructed by mucus a nasal sound is produced; this obstruction having the same effect as the voluntary closure of the anterior opening of the nostrils. In the second mode by which the nasal sound is produced, the nostrils are open, the larynx ascends considerably, the arches of the palate contract, the upper surface of the tongue ascends towards the palate, so that the air passes between the narrowed arches of the palate, and receives the resonance of the nasal cavities without that of the cavity of the mouth. The deficiency of tone in the voice of old people arises from the ossification of the cartilages of the larynx, and the altered state of the vocal cords. It is unsteady, owing to the loss of nervous command over the muscles.

The strength of the voice depends partly on the extent to which the vocal cords are capable of vibration, and partly on the great capacity of the chest, and the fitness of the various parts over which the air passes for communicating resonance. The intensity or loudness of a given note cannot be rendered greater by the mere augmentation of the force of the current through the glottis. Such an increase of force in the current will raise the pitch both of the natural and falsetto notes. It is therefore concluded that the variation in the intensity of a note, without the alteration of its pitch, must depend on some other cause than the mere change in the force of the current. Such a provision plainly lies in the power of modifying the tension of the vocal cords. To render a note more intense, without increasing its pitch, the vocal cords must be relaxed in proportion as the force of the current of the breath through the glottis has increased. When it is desired to render a note fainter, an opposite mode of action must be adopted.

The failure of perfectness in the notes of the human voice may arise from many causes. Variations in the temperature of the atmosphere, and in its states of humidity, have a powerful influence on the pitch of the voice. While a cold, moist state of the atmosphere prevails in this country, the voices of singers become lower by two or three notes, while they regain their usual pitch when the air becomes dry. Mr. Bishop mentions that when Grassini came to this country, owing to the change of the air from that of Italy, her voice became one octave lower. After singing for two or three seasons her natural voice returned, but it had lost its attractions with the loss of the low tones which had gained her so great applause. After long singing dissonance of the voice is apt to arise; this is easily accounted for by the slight changes produced on the vocal cords in consequence of repeated tension, together with the fatigue of the muscles concerned, which, as in other cases of muscular contraction, at length cease accurately to obey the will, and hence arise unsteady movements.

Whistling.—Before leaving the subject of the human voice, whistling deserves a few words. The sound in whistling does not arise from the vibrations of the lips. Several experiments prove that the lips are not thrown into vibrations. They may be touched, covered, or may have a disc of cork with a central hole placed between them, and yet the same sounds will be produced. It has been supposed, then, that the air is thrown into sonorous vibration by friction against the borders of the opening. According to Müller, the cause of the vibration is the same friction of the air; but the vibration produced upon the borders of the opening throws the whole column of air in the mouth into vibrations, and the vibrations of this column of air, by a reciprocal influence, determine the rapidity of the vibrations of the air at the orifice. The only difference, according to him, between whistling and the sounds of a pipe is, that in whistling the whole column of air is in constant progressive motion through the tube and orifice, while in a pipe the air in the tube merely vibrates, and does not move as a current.

Speech.—Speech is peculiar to man. Because speech is not possessed by individuals deprived of the organs of voice or of hearing, it is not, therefore, to be concluded that it originates in the mere possession of these organs. Inferior animals are fully provided with the organs both of hearing and of voice, and yet, in all essential respects, they are destitute of speech. Speech, therefore, must be considered under the light of a potentiality of man's intelligence, the condition of the exercise of which is the presence of the organs of hearing and of voice. That is to say, man is born susceptible, by the development of his nervous system, of the acquisition of speech, provided his organs of hearing and voice are perfect. But if man be born susceptible of speech, it may be asked, why does not the deaf-mute invent a language? He does invent a language, but it is a language of expression independently of speech; he fails to express his inward feelings by the use of speech, because the defect of hearing prevents him from discovering the sounds which his voice is capable of producing. His language, therefore, is confined to the other modes of expression by which an intercommunication, however imperfect, can be carried on between men. The deaf-mute might undoubtedly carry the use of natural signs of expression much farther, were he not overwhelmed and overpowered by the multitude of ideas which his fellow-men around him possess, and are continually striving to make him understand. It may also be asked if, owing to this natural susceptibility of speech, every infant should not invent a language. In so far every infant does invent a language, but as, long before any progress is made in its language, the sounds which it continually hears are caught up, it is impossible to judge to what extent each individual is capable of carrying such an invention.

There is no more interesting speculation than to consider the several steps by which language must have arisen among men. It is easy to understand how, in the rudest community of mankind, conventional signs must have arisen of every description; nor is it difficult to perceive that those sounds of speech which are most easily produced would quickly form a large share of those conventional signs. But it forms no part of our present design to investigate the origin of languages; it is more to the purpose to consider, in a few words, how men came to understand the several acts concerned in speech. At a certain period, then, in the progress of mankind, it appears that languages of no inconsiderable extent had already been formed, and yet that no attention could have been paid to the individual sounds composing those languages. Men spoke, and in that speech employed words without the least reference to letters, and perhaps with none even to syllables. The curious inquiry, then, which arises is, in the first place, how men were led to reduce speech to letters; that is, to analyze words into their elementary sounds.

We may suppose that the difficulty of pronouncing certain sounds, such as the words of a foreign language, must have been the first circumstance which would lead men to reflect on the modes by which speech is produced. Man's natural curiosity would not fail to engage him more largely in this inquiry as soon as the subject was suggested. Little progress, however, could be made in this pursuit till some method of fixing the sounds by name, and of representing them to one's self, or to others, at periods more or less distant from their first recognition, was invented. It may be supposed that men had already acquired the art of depicting objects of sight, were it no more than rude representations made with a rod on the sands left by a receding sea. The idea, however, of representing a sound by such a symbol is plainly not of the same kind. To think of representing a sound by a symbol is manifestly a fresh step in discovery. It required, in short, an effort of invention to produce such a stretch of thought. But the moment the idea arose all difficulty must have vanished. Nothing was easier than to observe the similar simple sounds occurring in the compound sounds which constitute speech. The mere observation of the form of the mouth, as certain simple sounds are uttered, would be sufficient to afford a foundation for this kind of knowledge. What the original symbols corresponding to our modern alphabets were, is of little moment. The first alphabets, doubtless, consisted of the representatives of but a small number of sounds. It is easy, however, to perceive that as soon as this kind of investigation was fairly commenced, it would make rapid progress, there being no great difficulty in discovering the collocation of the several parts of the mouth concerned in the production of most of the simple sounds. Thus, by an easy analysis, syllable-sounds would be reduced to letter-sounds, and each letter would quickly come to be marked by a particular symbol. The most remarkable effect of this great discovery, simple as it seems to us, would unquestionably be the rapid multiplication of sound-symbols—that is to say, the vast extension of language. The greatness of the discovery hardly strikes us at the first sight. Some idea of the character of it is obtained from the fable of words spoken becoming frozen at the moment in their fixed forms, and not reaching the ear until the return of a more genial temperature. Letters, in short, are the pictures of sounds, by which any sound now pronounced is perpetuated, while the picture itself, or a copy of it, shall endure.

Speech, then, consists of combinations of sounds produced in the larynx, and variously modified in their transition through the oral or nasal passages outwards. No language exhausts all the sounds which can be produced in the passage of the voice outwards in this manner. Languages may be described as composed of those sounds which are most easily produced in the passage of the voice from the larynx outwards into the atmosphere. And languages differ from each other chiefly by presenting various predominant groups of such sounds. The chief distinction of the sounds of speech is according as they are transmitted through the oral canal before spoken of, or the nasal passage. Another important distinction between articulate sounds is, that some are only of momentary duration, taking place during a sudden change in the conformation of the mouth, and are not capable of prolongation by a continued effusion of the breath, while others can be prolonged all the while that a particular disposition of the mouth and a constant expiration are maintained.

The same sound produced in the larynx is converted into any one of the vowel-sounds merely by a modification of the parts of the mouth through which it passes. The parts of the mouth concerned have been termed the oral canal and the oral opening. The oral canal, it is to be remembered, is the space between the tongue and the palate; the oral opening is the aperture formed by the lips. Some physiologists have described five degrees of size in each of these two parts—that is, five degrees of size in the oral canal, and five degrees of size in the oral opening. One sound, then, produced in the larynx is converted into *a*, *e*, *i*, *o*, *u*, according to the modifications in the size of these two parts. Thus when the size of the oral canal is in the third degree, and the size of the oral opening is in the fifth or highest degree, the act of voice is converted into the sound of the English *a* in *far*. When the size of the oral canal is in the second degree, and that of the oral opening in the fourth degree, the sound of the English *a* in *name* is produced. When the size of the oral canal is in the first or lowest degree, and that of the oral opening in the third degree, the sound of the English *e* in *theme* is produced. When the size of the oral canal is in the fourth degree, and that of the oral opening in the second degree, the sound of the English *o* is produced. When the size of the oral canal is in the fifth or highest degree, and that of the oral opening in the first or lowest degree, the sound of *u* like *oo* in *cool* is produced. Of the general truth of this statement any person may satisfy himself by remarking, when he utters the broad *a*, how much he opens his mouth, simply breathing forth the voice with open mouth. When, on the contrary, he with the same breath attempts to pronounce *e*, he finds the mouth close considerably, and the tongue rise towards the roof of the mouth, so as to contract the oral canal. In pronouncing *o* he will observe how the lips are thrown into the form of the letter, the tongue at the same time raised from the bottom of the mouth. The form of the vowel *o* in most languages points to one source of origin of those representations of sounds which we call alphabets.

Some consonants, like vowels, can be pronounced with an uninterrupted sound, which continues as long as the expiration can be prolonged, the disposition of the parts within the mouth remaining throughout as at the commencement of the sound. Of these, the aspirate *h* is pronounced with the whole oral canal open; no interruption is offered to the passage of the breath; its sound is the simple result of the resonance of the walls of the cavity during expiration. Others of the same class, such as *m*, *n*, and *ng*, are produced by continuous expiration through the nasal canal, the aperture of the mouth being closed either by the lips or by the tongue being pressed against the palate. The mouth is closed by the lips while *m* is pronounced, the sound being produced by the simple passage of the air through the nasal cavity. When *n* is pronounced, the mouth is closed by the extremity of the tongue being pressed against the fore part of the palate. *Ng* is regarded as a simple sound in the word *sing* and *bang*. It is produced also by the passage of sound through the nostril, while the posterior part of the tongue is pressed against the palate. Other consonants, again, of the same class, are continuous sounds developed by the valve-like application of different parts of the mouth to each other, such as *f*, *s*, *r*, *l*. *F* is pronounced by the application of the lower lip to the teeth. In pronouncing *s*, the teeth are brought into contact with each other, while the point of the tongue touches the lower teeth; in the sound of *r*, the tongue vibrates against the palate; in the sound of *l*, the point of the tongue is applied close to the palate, and the air escapes between the tongue and the cheeks. The English *th* is a modification of *s*.

The mute consonants with explosive sounds come next to be spoken of. The organs of speech by which these sounds are formed undergo a sudden change of position during their production. The sound commences with the closing of the mouth and terminates when it opens—that is to say, these consonants cannot be prolonged at pleasure; *b*, *g*, *d*, of which *p*, *k*, *t* are modifications, coming under this head. In sounding *b*, the lips are brought together and close the mouth, while they separate again at the moment the air is expired. In sounding *d*, the tongue is applied to the anterior part of the palate, or to the upper teeth, so as to close the mouth, which opens with the escape of the breath. In sounding *g*—that is, the hard *g*, as in *gold*—the momentary closure of the passage through the mouth takes place, more posteriorly, by the application of the back part of the tongue to the palate. In sounding *p*, *t*, and *k*, the requisite modifications of *b*, *d*, and *g* are produced by a stronger aspiration during the opening of the mouth, which was previously closed. All the sounds hitherto mentioned are capable of being pronounced in whispered speech. The English *y* and *z* cannot be uttered without an accompanying vocal sound. Thus, when an attempt is made to sound the English *y* in a whisper, the German *ch* is produced in its stead. All the vowels are capable of being produced equally in whispered speech, and with a vocal tone. Many consonants also, as *f*, *s*, *r*, *l*, *m*, *n*, *ng*, can be pronounced either with mute sounds or with vocal intonations. The continuous consonant *h* can only be pronounced in whispered voice; and it is quite impossible to combine the sounds of the explosive consonants, *b*, *d*, *g*, and their modifications, *p*, *t*, *k*, with an intonation of the voice.

Besides the ordinary sounds of consonants which enter into the formation of languages, other sounds are capable of being produced in the mouth and throat. The smacking sounds produced by the separation of the teeth from the tongue or palate, are reported by travellers to occur in the language of the Hottentots and in those of other African tribes.

The several sounds and tones of language can even be imitated by artificial contrivances. When the sound of the voice is made to pass into a cylindrical tube, before which the hand is held, and then withdrawn, the sound of *b* is produced; and if the tube be a pipe with a membranous tongue, the sound of *v* is produced. Various speaking machines, by attention to such principles, have been produced; the most perfect of these is that contrived by Faber. The automaton invented by Faber has a singing voice extending over twelve notes. The difference in the height of the notes is made by varying the width of the glottis without tension of the cords. In this respect it is hardly an exact model of the human organal voice.

The singular faculty possessed by ventriloquists has engaged much of the attention of physiologists. Many different views as to the nature of this kind of speech have been at various times brought forward.

One of the oldest and most common ideas on this subject is, that ventriloquism consists in speech produced during inspiration. It is unquestionably possible, though not without difficulty, to articulate during inspiration, and the sounds so produced have some resemblance to the tones uttered by a ventriloquist.

A more recent view of the nature of ventriloquism is, that it is a mere imitation, produced in the larynx, of the various modifications which the voice ordinarily suffers from distance, by the interposition of a partition, as if the individual were enclosed in a narrow space,—in a trunk, a cask, or the like. This view has been supported with much ingenuity by Magendie.

The distinguished German physiologist, Müller, has adopted an idea on this subject which coincides better with the original name of this artifice. He says that the notes of ventriloquism are produced by inspiring very deeply, so as to protrude the abdominal contents by the deep descent of the diaphragm, and the diaphragm being retained in this position, by speaking through a very narrow glottis, expiration is performed very slowly by the lateral walls of the chest alone. He affirms that the quality which the voice has in speaking through an expiration thus performed, is that peculiar to ventriloquism, and that sounds may be thus uttered which resemble the voice of a person calling from a distance.

A very large share of the artifice practiced by the ventriloquist, particularly in the imitation of voices coming from particular directions, lies in the deception of other senses besides the hearing. The directions in which sounds reach the ear are never very easily distinguished; and when the attention is drawn to a different point, the imagination is very apt to regard the sounds produced as coming from that quarter.

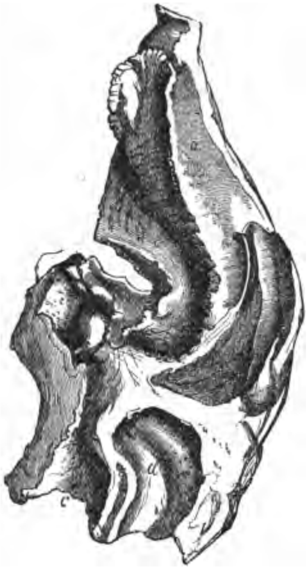
Of the imperfections of speech, stammering is that which has been chiefly investigated; and it lies in a momentary inability to pronounce a consonant or vowel, or to connect it with the preceding sounds. This impediment may occur either in the commencement or in the middle of a word. When the impediment arises in the middle of a word, the commencement of the word is often several times repeated. Hence stammering is apt to be defined as the successive repetition of one sound. The repetition of the commencement of the word, however, is not the essential defect which constitutes stammering; it merely marks repeated attempts to overcome the difficulty. Neither is it correct to say that the difficulty in stammering lies chiefly in pronouncing the consonants, for the impediment most frequently occurs in the case of vowels. The best account which has been given of the nature of stammering is, that it depends on the momentary closure of the glottis, so that the passage of the air necessary to the pronunciation of the particular sound is arrested. In persons severely affected with this impediment, there are manifest indications of the struggle at the glottis, occasioned by the impediment to expiration, in congestion of blood in the head and in the veins of the neck. The real cause of stammering, therefore, must be described as an unusual movement in the larynx, associated with the articulate movements. In short, stammering is a temporary spasmodic affection of the glottis. For the prevention of stammering, the proper plan is to endeavour to bring the associated movements of the larynx with the organs of speech more under the command of the will. To sing words is one method of obtaining this effect; since in singing more attention is directed to the action of the larynx than in ordinary speaking. Moreover, it is observed that persons who stammer pronounce better in singing than in mere speaking. The raising of the point of the tongue towards the palate has some effect in counteracting this habit, and this elevation of the tongue seems to have been the object of the plan practiced by the ancients, of placing bodies such as pebbles under the tongue. Müller recommends for the cure of stammering that the patient should practice himself in reading sentences in which all the letters which cannot be pronounced without a vowel sound—namely, the explosive consonants, *b*, *d*, *g*, *p*, *t*, and *k*—are omitted, and only those consonants included which are susceptible of an accompanying intonation of the voice. He also directs that all those letters should be very much prolonged. He says that by this means a mode of pronunciation will be attained in which the articulation is constantly combined with vocalization, and the glottis, consequently, never closed.

As already mentioned, dumbness is dependent, not on the defect of the organs of speech, but on the absence of hearing. By assiduous efforts deaf-mutes learn the movements of articulation by means of their sight. The speech which they acquire is most commonly harsh, owing to the want of the sense of hearing to regulate their articulation. There was no discovery hailed with greater interest than that of teaching the dumb to speak; and undoubtedly, harsh though the sounds be—and yet they are not always disagreeably harsh—there can hardly be a greater triumph of human art. It will hardly be believed that some innovators on the education of the deaf and dumb seek to abolish the practice of teaching them to articulate, on the ground that their harsh speech is unfitted for the uses of society, and that they can communicate with their fellows sufficiently by other means, as by speaking on the fingers and by writing. This is a most unwarrantable view of the case of these unhappy persons, particularly when they belong, as by far the major part of them must do, to the labouring classes of society. We have only to consider how many persons one in the condition of a labourer must meet with daily who cannot write, or read writing, to be satisfied that this innovation on the education of the deaf and dumb should be at once put down in every institution in which it has gained a footing. There is every reason to believe, that in proportion as a knowledge of the mode in which the sounds of the human voice in speech are produced becomes better understood, the artificial articulation of the deaf and dumb will become less and less harsh and disagreeable.

Comparative Physiology of Voice.—Organs of voice occur among inferior animals, in the mammalian tribes, birds, and reptiles. In mammals the organs of voice bear a close resemblance to those of man. In birds considerable modifications occur on these organs. In reptiles the apparatus of voice is of greater simplicity.

Voice of Mammals.—Among mammals some are mute, and yet these are not always deficient in those parts of the larynx which are most essential to voice.

Among the orders which compose the class mammalia, the cetaceans, consisting chiefly of the whale tribe, are often described as mute. These animals, however, are not mute altogether, but possess only a single lowing note, or at the utmost they have the power of simply bellowing. There are two distinct sections of cetaceans. The first includes what have been termed the herbivorous cetaceans, such as the sea-cow, *the representative of the popular mermaid*, and the dugong The second order includes the common cetaceans, popularly known as blowers. The act of blowing, from which they derive their name, consists in the expulsion of water by the nostrils; that is, along with their prey they receive a large quantity of water into the mouth, and while the mouth remains closed they blow out this superfluous water by a hole in the upper part of the head.



SECTION OF TONGUE, PHARYNX, AND LARYNX OF PORPOISE—*Museum of College of Surgeons of London.*
a, pyramidal position of larynx; *c*, pharynx; *d*, laryngeal cavities laid open.

This expulsion of water is produced by means of a peculiar arrangement of the veil of the palate. The water accumulates in a sac situated at the external orifice of the cavity of the nose, whence, by the compression of powerful muscles, it is violently expelled through a narrow aperture pierced on the summit of the head. By this contrivance these animals throw forth those jets of water which are seen by mariners at a great distance. The larynx has a pyramidal form, and penetrates into the posterior portion of the nostrils to receive air, and conduct it to the lungs, without the animal being obliged to raise its head and mouth above water for the purpose. As there are no projecting laminæ in the glottis, they can hardly be said to have the proper organs of voice, and thus the noise they make may be described as a simple vehemence of expiration.

The larynx, however, in these animals is highly developed in other respects.

Among the animals commonly described as mute is the giraffe or camel-leopard, termed by naturalists *Cameleo-pardalis giraffa*. In the giraffe the vocal ligaments appear to be absent.

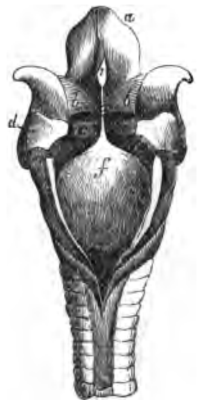
The armadillo (*Dasypus*) is another of the mammalians described as mute. The only peculiarity of the larynx which has been observed is, that the epiglottis, or valve-like cartilage of the larynx, is bilobed. The armadillo, it will be remembered, is remarkable among mammals for the scaly, hard, bony shell, composed of pavement-like compartments, which cover the head, the body, and even the tail. These animals belong to the order termed Edentata. They live in burrows, which they excavate. To the edentata also belong the ant-eaters (*Myrmecophagæ*), which are regarded as mute. In the same order is found the sloth (*Bradypus tridactylus*). In this animal, however, vocal ligaments are found, and the windpipe is convoluted. The voice is a plaintive melody, consisting of an ascending and descending scale of the hexachord.

Among the Rodentia, or gnawers, the common porcupine of Europe is mute. In this animal it has been ascertained that there are no vocal ligaments.

Such, then, are a few examples of the animals in the class Mammalia which are mute, or nearly mute.

In the order Ruminants we find animals possessed of a sonorous voice, exemplified particularly in the ox. In the ox the larynx is well developed; there are no superior vocal ligaments, but the inferior or true vocal ligaments are strong, and nearly an inch in length; the windpipe consists of fifty-two cartilaginous rings, that is, nearly three times as many as their number in man. The voice is sonorous, intense—pitched in C = 256 vibrations in a second.

The sheep belongs to the same order of quadrupeds. The larynx differs from that of the ox only in dimensions. The voice is guttural, pitched in F = 341 vibrations in a second.

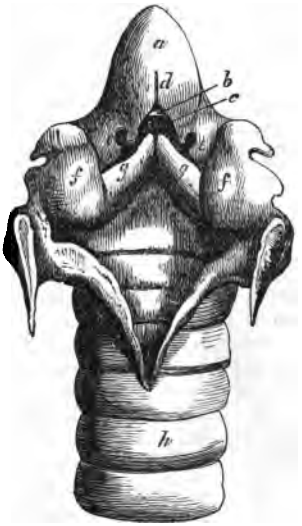


LARYNX OF CAMEL LAID OPEN—*Bishop.*

a, epiglottis; *b*, superior vocal cords; *c*, inferior; *d*, arytenoid cartilages; *e*, vertical ridge; *h*, tubercle; *f*, trachea.

To the same order belongs the camel (*Camelus Bactrianus*). In the camel the larynx is well developed; the superior vocal ligaments are present, and the inferior vocal ligaments are strong. The voice is grave, but seldom exercised.

In the Pachydermata, or thick-skinned animals, there are many species possessed of a sonorous voice. Among these are the horse, the ass, the hog, the rhinoceros, and the elephant. In the horse the larynx is highly developed, and the windpipe has as many cartilaginous rings as that of the ox. The superior vocal ligaments are not prominent. Above the junction of the proper vocal ligaments, between that and the epiglottis, there is an oval cavity, and on the posterior surface of the epiglottis there is a groove, furnished at its base with a semi-lunar membrane. To this membrane much effect has been ascribed in the production of the peculiar neighing of the horse. It is doubtful, however, if this peculiar sound be so much dependent on this membrane as has been believed.



LARYNX OF HORSE—*Bishop.*

a, epiglottis; *b*, semi-lunar membrane; *c*, aperture at base of the epiglottis; *d*, groove; *e*, ventricles; *f*, arytenoids; *g*, inferior vocal cords; *h*, trachea.

In the ass the larynx is also well developed. In the windpipe the rings are spiral. The bray of the ass—which seems greatly to depend upon the presence of two large sacs placed between the vocal ligaments and the internal surface of the thyroid—is well known; it has a range of about five tones.

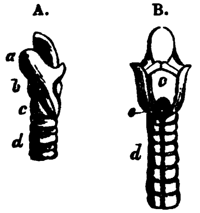
In the mule the larynx resembles that of the ass. The voice is a species of bray, more resembling that of the ass than the neighing of the horse. The tapir (*Tapir Americanus*) has some peculiarities in its larynx. It has, however, superior vocal ligaments, which are short and distinct, and inferior vocal ligaments, which are strong. The voice is a species of whistle.

The hog (*Sus scrofa*) has also some peculiarities in its larynx; its voice, as is well known, is a grunting, discordant sound.

The rhinoceros is remarkable for having the superior vocal cords very prominent.

In elephants the larynx is largely developed. The superior vocal ligaments are indistinct; the inferior or proper vocal ligaments are strong. The windpipe exhibits thirty rings, which are often partially subdivided, as in the case of the bronchial ramifications. The voice, aided by the trunk, is intense, and of a grave pitch.

Under the head of Marsupial animals, we find the kangaroo and the opossum.



A. LATERAL VIEW OF LARYNX OF DIDELPHIS OPOSSUM.

a, thyroid cartilage; *b*, cricoid; *c*, crico-thyroid ligament; *d*, trachea.

B. POSTERIOR VIEW OF THE SAME.

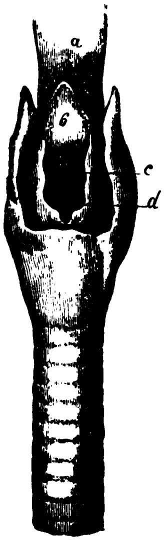
c, cricoid; *e*, laryngo-tracheal ligament; *d*, trachea.

In the kangaroo (*Macropus major*) several peculiarities occur in the larynx. In particular, the vocal cords are membranous, and fold upon themselves, so that they cannot be stretched by the arytenoids. The voice when in pain consists of a piteous moan. In the opossum (*Didelphis opossum*) the vocal ligaments are very short, hence the voice is acute. The opossum purrs like a cat.

In the order Carnivora we find examples of animals with intense voice.

In the lion (*Felis leo*) the larynx is well developed; the vocal ligaments, both superior and inferior, are present; the superior being prominent. The ventricles of the larynx are deep, forming a sac between the upper and under vocal ligaments. The windpipe is possessed of fifty cartilaginous rings. The voice is grave, highly intense, the roar terrific.

The tiger (*Felis tigris*) has a larynx resembling that of the lion, the superior vocal ligaments being very prominent. The voice of the tiger is more acute than that of the lion. It purrs like the cat. The leopard and the cat belong to the same genus, *Felis leopardus* and *Felis catus*. These two animals, like the rest of the feline tribe, have the superior vocal ligaments well developed. It is supposed that by these superior vocal ligaments the purring sound is produced. The voice in both animals is a mewing—they have by night a melancholy cry.



LARYNX OF CAT.

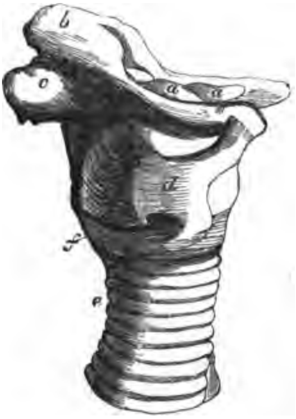
a, tongue; *b*, epiglottis; *c*, superior vocal cords; *d*, inferior vocal cords.

In the order Quadrumana, to which the apes and monkeys belong, the essential form of the organ of voice does not vary much, but peculiarities occur in the resounding walls. Thus in the ourang-outang a sac exists between the thyroid cartilage and hyoid bone, and in the mandrill, pavian, and macacos, membranous sacs are observed below the hyoid bone. In the Mycetes, or howling apes of the New World, the apparatus for the resonance of the voice is greatest. In these the hyoid bone and the thyroid cartilage are expanded in such a manner as to contain large cavities, which open into the ventricles of the larynx, and besides this there appear to be sacs common to the larynx and pharynx. Further, the epiglottis in these apes has a very large and peculiar form. In the Sapajous (Ateles and Cebus) a curved tube is formed by the increased size and altered forms of the epiglottis, and some adjacent structures. The voice of these animals has a whistling character.

In the chimpanzee the true vocal ligaments are prominent. The windpipe has sixteen rings. The voice is more acute than in women; its quality inferior, owing probably to the sacculated larynx. In the ourang-outang the inferior vocal ligaments are prominent, but not so long as in the families of the human race. The ventricles are valvular, so that the inflation of the peculiar sacs is under the control of the animal.

In the Gibbons the ventricles are deep, and communicate with a sac. The voice is acute; the cry "bow wow."

In the monkeys of the old continent there are also laryngeal sacs. These sacs modify the quality of the voice, giving to it, even when acute, a peculiar hoarseness. In the Simia appella and Simia capucina, there are some peculiarities in the structure of the channel for the passage of air. The voice in quality is like that of a flute; hence these are called whistling apes, and, from the peculiar expression of this whistle, which is a plaintive melody, they are termed weeping apes.



LATERAL VIEW OF LARYNX OF CHIMPANZEE. *aa*, sac connected with the lateral ventricle; *b*, hyoid bone, with *c*, sac protruding at its base; *d*, thyroid; *e*, trachea; *f*, cricoid.

Voice of Birds.—The great peculiarity in the organs of voice among birds is the inferior larynx; that is, birds, in addition to the larynx corresponding to that possessed by mammals, have one peculiar to themselves at the inferior extremity of the windpipe. Even the superior larynx of birds differs considerably from the larynx in mammals. The superior larynx, like that of mammals, is placed just below the hyoid bone. It is partly cartilaginous and partly osseous. In the superior larynx of birds there are cartilages corresponding to the thyroid and the cricoid, the two arytenoid, and the epiglottis. The cricoid is much less developed than in mammals; it forms but a small portion of a ring, occupying the posterior part of the larynx, and supporting, as in mammals, the two arytenoid cartilages. The thyroid cartilage, consequently, rests on the first ring of the windpipe. To the posterior margins of the thyroid cartilage are connected two quadrilateral bones, by which the extent of the protection afforded by the wings of the thyroid cartilage is much increased. The arytenoid cartilages are long, and taper upwards and downwards; they form by their inner margins the chink of the glottis. They are generally ossified; their external margins are bounded by the thyroid cartilage. The epiglottis in most birds is rudimentary, and generally is osseous. The chink of the glottis in birds is triangular, the apex being

SECTION OF INFERIOR LARYNX OF BIRDS.

directed upwards. It is bounded in front by the thyroid cartilage, on each side by the arytenoid cartilages, and behind by the cricoid cartilages; but it has no salient membranous laminæ, such as the vocal ligaments in man and mammals are. It is capable of expansion and contraction under the action of several muscles. The inferior larynx is, as we have seen, peculiar to birds. It varies very much in form and structure. This larynx, the vocal instrument of birds, is a tube, at the opening of which is a membranous tongue. This tongue is a doubling of the interior lining of the bronchus, its free margin being directed upwards; and birds have for the most part a smaller or greater number of muscles, capable of shortening this tongue or of lengthening it in the direction of its height, and of rendering it tense or lax in a transverse direction.

In general the inferior larynx of birds is produced by a membrane which makes a projection on each side of the inferior orifice of the windpipe; this orifice is divided into two apertures, sometimes by an osseous bar passing from before backwards, sometimes merely by the angle of union between the two bronchial divisions of the windpipe. The bronchi are not composed, like the windpipe, of complete rings, but merely of osseous or cartilaginous segments of rings of a greater or smaller number of degrees in extent, each having a proper curvature in the state of rest, which curvature may vary to a certain amount by the action of voluntary muscles.

It hence follows, that the portions of the walls of the two bronchial divisions of the windpipe, adjacent to (that is, looking towards) each other, are for a greater or smaller extent membranous, being there destitute of any osseous or cartilaginous structure; and it is to this usually large portion of the wall of each bronchus to which Cuvier gives the name tympaniform membrane. Thus two tympaniform membranes descend looking towards each other from the angle at which the windpipe divides, forming the interior wall of each of its subdivisions, and being extended transversely between the anterior and posterior extremities of the upper osseous segments of these same subdivisions; these osseous segments extending only along the posterior, the external and anterior part of their wall, so as to leave the inner part of each bronchus simply of a membranous structure.

The first osseous segment of each bronchus has much the same curvature as the windpipe itself; but the second and third are portions of larger circles, and are less convex exteriorly than the first, so that these last project on the inner side of the tube.

On this interior projecting part the lining membrane forms a fold, and it is this fold, half shutting one of the inferior apertures of the windpipe, which offers to the air issuing forth a tongue capable of vibrating and of producing sound.

The inferior larynx of singing birds, and some other birds whose voice is far from musical, is very complicated. The last rings of the windpipe unite into a structure two or three lines in length, nearly cylindrical above, and expanded below, where it has two obtuse points, one anterior, another posterior, joined by the bony bar passing from before backwards already spoken of more than once. This bar is so placed that the windpipe opens below by two oval holes, making with each other an obtuse angle, and each of these holes communicates with one of the bronchi.

The three first osseous segments of each bronchus are more near to each other and flatter than those which succeed them. From the first to the third there is a gradual elongation behind, so that the posterior extremity of the last makes a sort of projection, owing to the sudden diminution of the fourth segment. The arc which these segments form hardly exceeds 60°, and in each bronchus the cord of this arc, so to speak, is the tympaniform membrane. The first segment of each bronchus curves its anterior extremity towards the inner surface of the tube, where it articulates with a small oval cartilage which is fixed to the tympaniform membrane, while it forms within a prominence which is the vibrating lamina of the larynx on that side. Thus the transverse section of each bronchus is below nearly circular, the section higher up becomes the segment of a circle which diminishes in one direction while it enlarges in another; and the passage of the air upwards into the windpipe takes place by two oval holes, each furnished at its anterior border with a salient lamina. This apparatus is supplied with ten muscles, five on each side.

Of these, one descends from the interior of the windpipe to the anterior extremity of the third segment of the bronchus, and, by its contraction, draws that point upwards, thereby making the vibrating lamina project farther inwards, and, at the same time, rendering tense lengthwise all that part of the tympaniform membrane lying below the segment to which the muscle is attached. Another muscle parallel to this has nearly the same attachments, and a like office. A third muscle, much smaller, extends from the inferior and posterior part of the windpipe, and is inserted into the posterior extremity of the second bronchial segment. Its action is similar to that of the former. A fourth muscle passes obliquely from the windpipe to the posterior extremity of the second bronchial segment. It draws that segment upwards and outwards, so as to aid the action of the muscles already referred to, and of that which follows. The fifth muscle is no longer than the preceding, but is much thicker. Taking its origin from the last ring of the windpipe, it passes downwards and forwards, and is inserted into the anterior extremity of the first bronchial segment, and particularly into the minute cartilage already mentioned as being articulated with that point. Its chief action is to draw forward the small cartilage, and consequently forcibly to put on the stretch, in a transverse direction, the upper part of the tympaniform membrane.

Such a complex structure of the inferior larynx belongs, as was hinted at, not only to singing birds—such as the nightingale, the wren, the blackbird, the goldfinch, the lark, the linnet, the canary, and chaffinch—and to those with a monotonous cry, like the swallow, the sparrow, the starling; but also to some with a decidedly disagreeable cry, such as the jay, the magpie, the crow, the raven. Thus not only is a complex organ necessary to the musical singing of birds, but also a fine general organization and a singing instinct.

The windpipe in birds presents some very singular modifications. As the voice is produced in the inferior larynx of birds, situated at the lower part of the windpipe, this tube comes to form, together with the mouth, the tube or pipe placed in front of the organ of voice. In short, the windpipe of birds comes to occupy a place corresponding to the situation of the organs of speech in the human body. It is capable of being shortened, not only by the diminution of the spaces between the rings themselves, but also by the rings being received one within the other. In many birds the windpipe is much longer than the neck, being thrown into convolutions. This structure is observed in the cock-of-the-wood, the stork, and crane. In the wild swan the convolutions of the windpipe are lodged in a cavity of the breast bone. Nor is the windpipe always cylindrical, for in herons and cormorants it has a conical figure, becoming gradually wider and wider towards the mouth. In some species of ducks it presents a sudden dilatation, while in the goosander, and some members of the duck family, it undergoes gradual dilatations.

That the inferior larynx of birds is the true organ of voice has been proved by many experiments. For example, anatomists have divided the windpipe in singing birds, such as the blackbird, about the middle of its length, so that the air could no longer pass through the superior larynx, and yet the bird would continue to sing, though with feebler tones than before. Similar experiments have been made on magpies and on ducks. After such an experiment, the magpie is found to cry with as great intensity of tone and with the same acuteness as before the operation. Again, if air is blown into the bronchial divisions of a duck after their separation together with the inferior larynx from the body, a sound exactly similar to the natural cry of the bird is obtained. Even after the bronchi have been cut away, by blowing into the trachea the same sound is produced.

It is not, however, to be concluded that the superior larynx exerts no modifying influence on the voice in most birds. It is manifestly opened and closed rapidly in singing birds, so that it is impossible to doubt that it takes an active part in the production of melody. In the song of the canary and the linnet its simultaneous movements with those of the mouth are readily observed. Its effect, however, on the pitch of the voice is not supposed to exceed a semi-tone. Physiologists still doubt whether the sounds of the voice in birds are the result, as in man, of the vibrations of a reed or tongue, or, as in mere flute-pipes, of the vibrations of a column of air excited by friction against the lips of an opening. There is unquestionably a great difference in the mode in which voice is produced in different birds. It seems certain that the simple organ of voice in the duck, the goose, and the like, is a reed instrument. In these the vocal cords, or bands, which form the exterior margin of the opening of the larynx, can be seen to vibrate strongly, while the sound produced closely resembles that arising from the vibrations of membranes. But it is by no means so clear that the piping, whistling sounds of singing birds are produced in the same manner; and it is not impossible that these may be effected in the same mode as whistling by the mouth in man.

Several reasons, however, may be urged in favour of the opinion that the sounds uttered by singing birds are the effect of the vibrations of tongues, as well as the voice of the duck and the goose. For example, the vocal cords under muscular action can hardly escape being thrown into vibrations; and even though the friction of the air may be in part concerned in the production of the sounds, a compensation must arise between the vibrations of the air and those of the vocal ligaments. If this be correct, the organ of voice in birds would not be entirely analogous to a whistle or pipe, but would in part possess the constitution of a reed instrument. It is found that the length of the windpipe has but a very slight influence on the note produced by the larynx; and that fact corresponds with the slight effect on the pitch of the notes produced by placing a tube in front of the human larynx. It is also found that sounds produced by blowing, by means of a tube inserted in a bronchus through the lower larynx of some birds after its separation from the windpipe, are not perceptibly altered in pitch by holding a tube in front of the larynx: thus is confirmed the resemblance of the lower larynx in birds to the character of the larynx in man. It may be added, that the greater number of the notes of birds may be obtained from the inferior larynx by varying the force of the blast, which at first sight seems to point to a resemblance with the effect of blowing by varying force upon the notes of flute-pipes of the same size as the windpipe of small singing birds. But it is to be remembered that the same variations of notes, by varying the strength of the blast, may be produced in reed instruments with membranous tongues, and even in reeds with very delicate metallic tongues.

The influence of the windpipe on the notes may be either the same as that of the notes of flute pipes, or it may merely influence the notes in the manner of the tube of reed instruments. Contraction of the upper opening of the windpipe at the superior larynx may lower the note, as in pipes and reed instruments.

An influence may be exerted on the sounds produced in the lower larynx by the tympaniform membrane, which vibrates strongly at the time. Between the internal vocal cord, the semi-lunar membrane, and the tympaniform membrane, there is a relation of compensation, the latter being analogous to the membrane formed of a reed stalk.

The muscles which vary the tension of the walls of the vocal pipe are in continual action during the modulation of the voice, in order to adjust the tube of the windpipe to the pitch of the glottis; but the number of vibrations may be determined by the glottis, reinforced by the walls of the pipe, as in mammals.

The voice of birds, as of other animals, is also in a minor key. The range of notes is commonly within an octave, though some birds can greatly exceed it. In the parrots, which have a voice of great power, the inferior larynx is single. The two membranes of the larynx leave a narrow chink between them, through which the air is forced from the lungs. These membranes, vibrating in all their dimensions, produce that harsh and disagreeable quality of sound peculiar to them. They can also whistle, during which the glottis is probably silent, and the column of air vibrates as in a flute, when a vibratory movement is communicated by the air traversing the elastic walls of the tube. Besides the power of speech possessed by some birds, many can imitate almost every sound they hear; the blackbird has been known to imitate the sound of the nightingale, the crowing of the common cock, and the cackle of the hen. The jay is said to mock the notes of the greenfinch and the neighing of the horse so closely that it was scarcely believed to be a bird by those who heard it, also the calling of fowls to their food, and the barking of the house-dog.

The variety in the song of singing birds is a subject of the greatest interest. The songsters, properly so called, include the skylark, the woodlark, the thrush, the blackbird, and the nightingale. A slight notice of the notes of each of these follows:

The skylark is one of our most agreeable songsters. Its song is composed of several strains, each consisting of trilling and warbling notes variously modulated, occasionally interrupted by a powerful whistling. Sometimes the lark sings on the ground, perched on a clod, or crouched among the grass; but generally in commencing its song it starts off, rises perpendicularly or obliquely in the air, with a fluttering motion, and continues it till it has attained its highest elevation, which not unfrequently is such as to render the bird scarcely perceptible. Even then, as remarked by a distinguished naturalist, if the weather be calm, you hear its warble coming faintly on the ear at intervals. The lark is also a bird of singular capacity; the young learn the notes of any other bird which hangs near them in confinement, and some full-grown birds are observed to possess a like facility. There is, however, a considerable difference among larks in the strength and melodiousness of the note. In confinement some larks begin to sing as early as November, and go on singing until moulting time; others begin in March, and cease as early as August. In the wild state their period of singing is much shortened.

The woodlark is considerably less than the skylark, but of all the larks it is the sweetest songster. Its voice has all the melody of the flute, marked at times by a tender and even somewhat melancholy strain. It sings sometimes in the air, sometimes on the top of a tree. When singing in the air it is frequently seen flying in large, irregular circles. The woodlark sings late in the evening, so as sometimes to be mistaken for the nightingale. The female woodlark, like the female of larks in general, is not destitute of song; but all that it can reach is a few strophes much interrupted.

The thrush has a clear and beautiful song. On the tops of the highest trees it welcomes the approach of spring, and sings throughout the whole summer, especially in the morning dawn and the evening twilight. It is kept in a cage by bird-fanciers, whence often on a morning, even as early as February, it will delight a whole street by its pleasing song, outside the window, or even inside, provided the window be a little open. The thrush in its wild state is fond of bathing. In September and October they are often caught at the places where they water, before sunrise and after sunset, and even so late that they cannot be seen, but are only heard. At the time of bathing they have a peculiar call-note. When a thrush finds water, or when it is flying towards a known watering place, it pipes loudly *sik*, *sik*, *sik*, *sik*, *siki*, *tsak*, *tsak!* and immediately all the thrushes in the neighbourhood reply, and come on.

The blackbird has a song rich in melody, containing some deep notes, like those of the nightingale, yet varied with some which are unpleasantly harsh. When at liberty it sings from March to July, particularly at night. In the cage it sings throughout the whole year, except at moulting time. Its note is pure, distinct, and clear. It has a good memory, and will learn several airs or melodies without confusing them. It is even able to imitate words.

The nightingale by the fineness of its voice surpasses every other bird. The variety and peculiarity of its tones express its varying emotions. When the male is alone, its most significant note is the pipe-note *witt*. But if the harsh syllable, *krr*, be added, it forms the call of the male to the female. To express anger or fear the note *witt* is repeated with great loudness and rapidity before the termination *krr* is added. When happy and contented the nightingale utters a deep *tack*. Under the excitement of anger, jealousy, or alarm, the nightingale utters an unpleasant shrieking tone, which resembles the cry of the jay. When they sport and chase each other, which they frequently do in pairing time, they utter a very short chirping sound. Such notes belong to both sexes; but the power and the brilliancy of his song distinguishes the male. His vocal organ is of striking power; the muscles of his throat are more robust than those of any other singing bird. Besides the strength of his voice, the nightingale is remarkable for the force, the agreeable transitions, and the beautiful harmony of his song. Commencing softly, he warbles for a moment a succession of low melancholy notes, which gradually increase in strength, and at last die away upon the ear. A variety of sharp notes follows, and then are uttered numerous hurried sharp notes, intermingled with some detached ascending notes, with which he generally closes his strain. In the song of a fine nightingale, without reference to slighter variations, there are at least four-and-twenty different strains.

Among the sparrow and finch tribes there are many much prized singing birds.

The bullfinch has naturally a harsh, creaking tone, but young birds learn all kinds of songs, airs, and melodies. If it be desired that a bullfinch should sing perfectly, it ought never to be taught more than one melody, in addition to the fanfare, which is always added by way of surplus.

The chaffinch has a variety of notes expressive of its wants and desires. There is one delicate note, expressed *treef*, *treef*, by which it appears to remark a change of temperature. The call-note, which it uses chiefly on its migration, is a repeated *yack, yack*. A spontaneous sound appears to be *fink, fink*, which it reiterates, and from which perhaps the root of its name is derived. More remarkable than these notes is its clear and trilling song; as approaching more to distinct articulation, it is termed a quaver. Each bird has one, two, three, and often as many as four different songs, each of which lasts a couple of seconds, and consists of several strophes. Those who desire a particular account of the different songs of the chaffinch, may consult "Chamber Birds," by Bechstein, translated from the German by Mr. Shuckard, London, 1848.

The linnet has a very remarkable. loud, and flute-like song, consisting of many connected strophes, which is the more beautiful the oftener it utters some high-sounding notes, which are termed its crowing, from the resemblance to the crowing of a cock. From its natural flute-like voice, this bird surpasses all others in its capacity for imitating melodies in a beautiful and pure style. A young linnet taught by a nightingale has an exceedingly pleasing song.

The goldfinch has a shrill, agreeable song, heard during all seasons, except at the period of moulting. It contains many warbling and twittering notes, on which it dwells more or less, and the oftener the syllable *fink* is repeated the more it is admired. Some birds utter these notes only once or twice in their song, while others give them forth four or five times in succession. The goldfinch does not acquire the song of other birds with so much ease as the linnet and the canary.

The canary is distinguished by correctness of ear, by the remarkable skill it possesses of imitating all tones, and by an excellent memory. While canaries imitate the notes of other birds, they mix them with their own, so as greatly to improve the song. In different countries canaries exhibit a different character of melody. Those birds which intermix in their melodies several strophes of the song of the nightingale, are called Tyrolese canaries. The English canaries, on the contrary, imitate the song of the lark.

Even birds of prey often exhibit no small extent of voice. The kestrel has a bell-like ringing voice, *kli, kli, kli*, which he often repeats in rapid succession. The white owl utters a plaintive cry, which by the superstitious has been regarded as a sign of death. The raven has a hoarse croak resembling the syllable *crock* or *cruck*, but it also utters a note not unlike the sound of a sudden gulp, or the syllable *cluck*, which it seems to utter when in a sportive mood. The rooks have a considerable variety of sounds. Their chief cry resembles the syllable *khraa*, more or less harsh or soft according to occasion. There is great diversity in the voice of individuals, the notes of some being much louder and clearer than those of others. Their cries, separately, are monotonous and disagreeable; yet when at some distance, and uttered by a large flock, they become by no means unpleasant. Mr. M'Gillivray describes the sounds proceeding from a rookery at night as consisting of a variety of soft, clear, modulated notes, very unlike their usual cry. He regarded these sounds as expressive of affection, and was persuaded that the mothers were fondling and coaxing the newly-hatched young.

The jackdaw is extremely clamorous, with a loud and clear note, resembling the syllable *kae* or *caw*, variously modulated. The noise produced by a large flock, though in no degree musical, is far from being disagreeable. The jay can even learn to speak, uttering, however, nothing but solitary words. They may be taught also the fanfare of a trumpet, and other melodies of single bars, as well as little airs and the notes of many birds. The magpie imitates all striking sounds, and can be taught to speak more easily than any other of the crow tribe. The cry of the cuckoo is universally welcome as the harbinger of spring. His principal sound is nothing but *hu-hu* or *coo-coo*, repeated at short intervals; when attention is given, however, it is found that these two loud and mellow notes are preceded by a kind of churring or chuckling sound, which consists of a low and guttural inflexion of the voice, during which the throat seems distended.

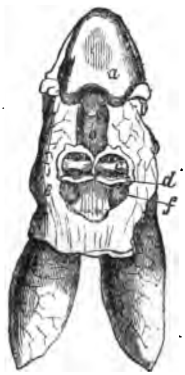
The parrot tribe are most remarkable for their power of imitating human speech. The cockatoo shrieks its own name, *cockatoo*, and calls loudly, in a trumpet-like tone, *derdeny*. The cries of all animals it acquires, particularly those of the domestic cock and hen. It rarely, however, acquires the power of articulating words. There are numerous species of cockatoo parrots having much the same character of voice. Among the commonest of the parrot tribe in Europe is the ash-coloured parrot. This parrot readily learns to speak, and to pipe. It has not the unpleasant wild shriek of some of the parrot tribe. It takes no small delight in imitating the voice of children; hence children are its best instructors. If its education be begun early, it will sometimes acquire entire verses, and even axioms.

The gray woodpecker has a note which resembles a loud shout of laughter, whence some of its popular names are derived; this note is never varied, except by its more clamorous repetition during the spring and early summer months, and by the peculiar cry, *plui*, *plui*, *plui*, which has been supposed to indicate the approach of rain. The wryneck in spring frequently and loudly utters *gigigigi*, which is the call whereby he attracts his mate. The nuthatch utters a loud call, which may be heard at a considerable distance, resembling *grew*, *deck*, *deck*. The ring-dove, or cushat, has a loud and particularly pleasing cooing, during which he makes very grotesque motions, which may be backwards and forwards, or from side to side, moving the head in every direction. The turtle dove has a peculiar cry, and bows his head while it is uttered.

Voice of Reptiles.—The sounds uttered by reptiles and amphibious animals have their source in the larynx, like the voice of mammals. In frogs, as well as in the crocodile, there are vocal cords. In the crocodile the larynx, though more simple than in mammals, still retains something of the same character. There is one large, long-shaped cartilage, to which are attached two movable cartilages. The mucous membrane descending from these movable cartilages into a deep pouch beneath, leaves a free fold on each side, which, when the movable cartilages approximate, becomes a vocal cord. In the gecko and the chameleon the vocal cords are more developed than in the crocodile, nevertheless they are formed on the same plan. The lizard has an acute, chirping voice, which has been supposed to depend on a peculiar membranous fold attached to the larynx, but it really seems to depend on a vibration of the margins of the glottis. In the turtle tribe there are no vocal cords, nor is their larynx adapted to a perfect intonation of the breath.

In the true serpents there are no vocal cords; the hissing sound which constitutes their imperfect voice is a mere forcible breathing. In the male frog membranous sacs at the side of the neck become distended in the utterance of the voice, and serve to increase its intensity. In the *Rana pipa*, in which the larynx, as in all other frogs, receives the bronchi directly, without the intervention of a windpipe, there is a large cartilaginous box, within which are two solid reed-like bodies, nearly as long as the larynx itself. The anterior extremities of these bodies are fixed; their posterior extremity is free, and projects on each side towards the opening of the bronchus. The vocal sound is produced by the vibrations of reed-shaped tongues, which act like a tuning-fork;

while in other animals of the same class the parts which produce the sound are membranous. If a small piece of cartilage, a few lines in length, be fixed by one end, and a current of air be thrown from a small tube upon its edge at the other extremity, a humming sound is heard. In the *Rana pipa*, also, the movable cartilages are convex externally, and concave internally; so that when the entrance to the larynx is closed, they form a dome over the windpipe, which has been compared to a kettle-drum. In the *Rana temporaria*, *R. esculenta* and *R. hyla*, the larynx opens into two sacs on either side of the lower jaw, and these, during the cry of the animal, are filled with air.



RANA TEMPORARIA (COMMON FROG)—*Bishop.* *a*, tongue; *b*, hyoid bone; *c*, superior vocal cords; *d*, inferior vocal cords; *e*, pharynx; *f*, right bronchus.

Sounds produced by Fishes.—A very few fishes are known to utter sounds, such as the trigla, cottus, pogonias.

The trigla utters a grunting sound when it is taken out of the water. It has been supposed that the peculiar muscle of the air-bladder in these animals has a share in causing the sound. The cottus, however, from which a sound is heard to proceed when pressure is made upon its body, has no air-bladder. The pogonias, on account of the sounds which it produces, has been named the tambour. These fishes produce continued sounds under the water. The air-bladder is very large, and is covered by strong muscles; further, it has appendages, which, according to Cuvier, pass between the ribs, and become embedded in the muscles.

Sounds produced by Insects.—Most insects are mute; others produce sounds merely by friction; others, again, by the passage of air through their spiracles. The sounds produced by friction come under the head of stridulation; those produced by air from the spiracles, purring or humming. In the orthoptera, and some of the coleoptera, there are parts adapted to produce stridulation.

In the cricket the muscular apparatus may be described as consisting of a serrated string like a file, which in the movement of the wings is drawn rapidly over a firm, transparent, and nearly triangular disc, or sounding-plate, surrounded by a string, and by this act the sound is produced. The pitch of the sound of the house-cricket is very acute, being equivalent to about 4096 vibrations in a second.

The cicadæ, termed sometimes the "*chanteuses*," or singers, are so called because the males produce, in the hottest part of the day, a kind of monotonous and noisy music:—

"Et cantu querulæ rumpent arbusta cicadæ."—VIRG.

The music of the grasshopper has from early times attracted attention. Archias sung of it, and his verse has been thus translated from the Greek:—

"Erst on the fir's green blooming branch, O grasshopper! 'twas thine
To sit—or on the shady spray of the dusky, tufted pine;
And from thy hollow, well-winged sides to sound the blythesome strain,
Sweeter than music of the lyre to the simple shepherd swain."

Those, too, who loved these "living lyres in the olive groves sounding all the summer long," have celebrated the locust:—

"Soother of loves, encourager of sleep,
O locust! mystic muse, shrill wing'd;"—

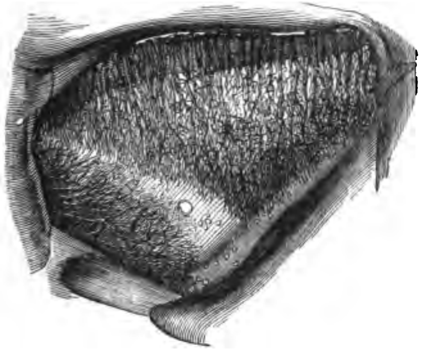
And the cicada,

> "Cicada! thou, who, tipsy with the dews
> Of weeping skies, on the tall poplar tree
> Perch'd swayingly, thyself dost still amuse,
> And the hush'd grove, with thy sweet minstrelsy."

Melanger, alluding to the buzzing of insects, says, "Excute facundas pedibus titubantibus alas":—

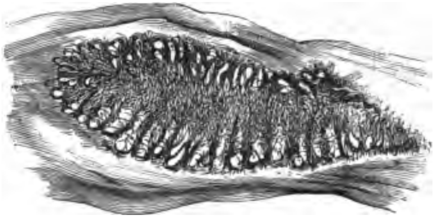
> "Striking thine own speaking wings with thy feet;"

but their real organs of sound are placed on the side of the base of the abdomen, internal, and covered by a cartilaginous plate, like a shutter, which is an appendage of the under side of the meta-thorax or posterior thorax. The cavity which incloses these instruments is divided into two partitions by a scaly and triangular edge. Seen from the under side of the body, each cell exhibits anteriorly a white and folded membrane, and in the hollow part a stretched out, slender membrane, called the mirror. If this part of the body be opened from above on each side, there is seen another folded membrane, which is moved by a very powerful muscle, composed of a great number of straight and parallel fibres, extending from the scaly ridge; this membrane is called the *timbale*. The muscles, by contracting and relaxing with quickness, act upon the *timbales*, stretching them out or bringing them into their natural state, whereby the sounds are produced, and which, even after the death of the animal, may be repeated by moving the parts over each other in the manner they act whilst alive. The cicadæ occur chiefly in warmer countries of the world. One species, the *Cicada Anglica*, the only English species, is found in the New Forest.



THORACIC SPIRACLE OF BLUE-BOTTLE FLY
(*Musca vomitoria*).

It is a common belief that the buzzing of insects is produced by the oscillations of their wings during flight. This idea has been often called in question. John Hunter found that insects emitted sounds after their wings were cut off. More recently it has been stated that the sounds produced by many insects are the effect of a rapid transmission of air through the thoracic air-holes as they dash through space. Mr. Bishop has observed a peculiar mechanism for this purpose in the blue-bottle fly and humble bee. The annexed figures show one of the large thoracic spiracles in each of these insects, the *Musca vomitoria* and the *Bombus terrestris*.



THORACIC SPIRACLE OF HUMBLE BEE
(*Bombus terrestris*).

The Application of Physiology.—After the foregoing details of the chief points in the economy of living nature, it will not, in conclusion, be inappropriate to exhibit some of the great truths of Physiology; to trace their connection with other subjects of human inquiry; and to point out some of the uses to which a knowledge of this department of science is practically applicable.

Physiology, taken in its largest acceptation, holds a most prominent place in the circle of human knowledge. We have seen it trace the development of the perfect man through the grass of the fields back to the common mineral elements of the crust of the earth. It also enlists in its service Anatomy, Chemistry, and not a few departments of general Physics; and it connects itself with Agriculture, Political Economy, and the science of Legislation and Government, hardly less than with Medicine, Surgery, and the preservation of health.

The most striking truth in physiology is, that organic existences, including alike the highest races of mankind and the meanest vegetable organisms, are, in their material composition, derived from the mineral matter of the earth. The properties of the simple elementary substances entering into the vegetable and the animal kingdom have been ascertained with exactness; in their mineral condition, they have been fully investigated; and their chemical properties and combinations in inorganic nature are well understood. And such knowledge leads to a second great principle in physiology—namely, that there is nothing in the properties of these several elements of the organic world by which any tendency is given to them, beyond the rest of mineral matter, to combine together to produce any form of organic life, however simple, and however transitory. When, then, in connection with this undeniable truth, it is considered that, for long periods of time, our planet, the earth, must have been, from physical circumstances, totally incapable of supporting any form of organic existence, the conclusion follows, that the appearance of organic existences on the earth implies an exercise of Infinite Power, by which mineral matter was endowed with the new property of passing into the first species of animal and vegetable life. It is vain to say that such statements as these lie without the pale of inductive science. Man's natural curiosity loudly asks. whence came organic species, whenever he considers the undeniable truth that the surface of the earth must have lain for ages destitute of such existences; and the answer which, by the original constitution of his mind, he is compelled to give, is, that such a change on the mere matter of the crust of the earth, as its transition into living forms, could not have occurred without the interposition of Omnipotent Power.

This great truth, then, is not the less a natural inference of the human faculties, because it does not strictly fall within the limits of physiology; it owes its origin to the operation of the great principles of human belief, implanted in the mind by its primitive constitution, and on the knowledge supplied by the cultivation of physiology. The next great step in the progress of man's knowledge of organic nature lies strikingly within the limits of physiological science. It is the conclusion that each organic species had its origin in a separate creative power. It is vain for any one pretending to the character of a philosopher to maintain that the idea of a transmutation of species is far more simple and far more in accordance with Infinite Wisdom. Every one endowed with a philosophic spirit must at once reject this idea, simply because there is not a shadow of foundation in its behalf to be met with in the whole of nature. It is impossible to pronounce with certainty, from physiological evidence, whether the several races of plants and animals at present living, or discovered by geological evidence to have formerly existed, had their origin from one pair, or from many pairs; but the strongest evidence does exist against the supposition that one species of a lower grade can pass successively into other species of a higher grade. On the contrary, nature has guarded each species from change with the most sedulous care. By artificial means, and within certain limits, man can make various changes in the species, both of plants and animals; and accidental circumstances, without man's interference, produce like variations. But it is fully ascertained that, as soon as those circumstances, whether designed or accidental, which have caused a variation have ceased to operate, then the species returns to its original state.

As soon as physiology, by drawing upon the philosophy of mind, has overcome the difficulty attendant on the first appearance of organic nature on the surface of the earth, it traces out by observation all that belongs to the economy of organic existence. By such observations physiology has made known the conditions necessary for the development and maintenance of organic existences as well as for their reproduction; and as far as physiology has yet discovered, so long as these conditions can be maintained in respect to each species, no tendency is shown to its becoming extinct. At the same time, a question may arise whether organic species have the power of unlimited existence, as species, so long as the ordinary known conditions necessary for the maintenance of the individuals continue unimpaired, or whether a species be, like the individual, capable only of a limited existence; so that, as in the case of the individuals of which it is composed, its prolific life at last begins to fail. The experience of mankind on the earth is probably not yet sufficiently extended to afford any sufficient data for debating this question. But the striking analogies between individual life and the life of a species in other respects, must prevent us from positively affirming that species can only die by a failure in the ordinary conditions under which the individuals of that species are seen at present to live and thrive. In the case of the individuals of every species, no matter how abundantly the conditions of their life are supplied, there comes at last a period when their susceptibility of availing themselves of those conditions declines, so that decay and death are the inevitable consequences. In the species of plants and animals best known to physiologists, no tendency has ever yet been remarked to degenerate, except that which owed its origin to a failure in the conditions necessary for the existence of the individuals of that species. The dodo is an example of a species which has become extinct within the records of history; but a single case hardly affords a sufficient ground even for conjecture; and it is, perhaps, right at present for physiologists to content themselves with the belief that the dodo perished from fortuitous causes interfering with the external conditions necessary to enable the individuals of that species to live and thrive on the earth's surface.

Here, however, in stating the great truths of physiology, the importance of the law of death in the organic world, as taking that part of nature entirely out of the category in which mineral nature exists, must not be omitted. In physiological nature, then, the law of death may be thus stated—no perfection of organism, no completeness in the supply of the conditions of existence, can prevent any living individual whatever from at last failing to derive the means of maintenance from those conditions, and from falling into a state of decay and dissolution. Such a law is exclusively known in physiological nature, there being nothing the least analogous to it in the case of inert matter.

A more practical truth of physiology is, that each species multiplies in proportion as the circumstances under which it is placed are favourable to the maintenance of the individuals of that species. This law appears to admit of no exception. In short, physiological principles are quite sufficient to settle the questions whch have arisen as respects the law of population. No country can support more inhabitants than it can supply with the means of maintenance. It is not necessary that the soil of that country should produce enough of corn and cattle to feed all its inhabitants; but then it must produce something else by means of which food can be obtained from other countries. If the inhabitants are skillful workmen, they may convert raw material, derived from other countries, into manufactured goods; and for the value of their workmanship they may receive enough of corn and cattle to satisfy their wants. There may be mines of mineral wealth in demand among agricultural nations; and in exchange for this wealth they may obtain a sufficiency of corn and cattle. Still the great law remains unaffected that the number of people which a country can maintain cannot exceed that for which it possesses the means of providing food.

Physiology enters upon another practical question of vast importance—namely, whether the soil of a country can be renewed independently of the application of existing organic matter. Every crop which is taken off a field carries with it a certain amount of soil; not, indeed, equal to its actual weight. because a great part of the substance of each crop is derived from the air, and from the rains. Hence a soil necessarily becomes exhausted by repeated crops. It is renewed by the application of manure; but as manure, in common circumstances, is obtained from organic matter, it is plain that the organic matter of a country must be continually declining by being again reduced to mineral matter; unless it be proved that under some circumstances at least soil can be renewed from the mineral kingdom. The annual waste of organic matter in every country is enormous—that is to say, a large quantity of organic matter is continually passing back into the mineral state, under such processes as putrefaction, combustion, and the respiration of animals. Plants, no doubt, are continually converting inorganic matter, such as the carbon of carbonic acid and the hydrogen of water, into their own substance. But the organic substances required for food contain not only hydrogen and carbon, but also nitrogen; and therefore, unless it be proved that ammonia, which is the chief source of the nitrogen of plants, be constantly produced in the mineral kingdom, it must be confessed that there is a continued irreparable destruction of organic matter upon the earth's surface. Here there is a controversy among chemical authorities—some contending that ammonia is continually formed in the mineral kingdom; others that the ammonia which appears in a soil is derived solely from the decomposition of organic matter. On the determination of this question our speculations rest as to the future history of the organic kingdoms on the surface of our planet. If there be a continual destruction of organic matter without any corresponding renewal from the mineral kingdom, then a time will come when plants and animals must perish for want of the means of subsistence at present supplied to them by the soil. It is no part of our purpose to enter upon this controversy; but the evidence at present seems to be in favour of the unlimited power of mineral nature to produce ammonia, and therefore to supply that important constituent of the food of plants which otherwise must be derived from the destruction of organic matter.

Another speculative question bearing on the fortunes of the animal kingdom is sometimes debated in works of physiology. We have already remarked, that the carbonic acid, which is continually thrown into the atmosphere by the respiration of animals, is as constantly decomposed and removed by plants for their own support. It is a common view that our atmosphere must, at a very early period, have contained all the carbon, in the form of carbonic acid, which now exists in the organic kingdoms, and in the soil of the earth. If such were the case, the atmosphere, however fit to support the life of vegetable organisms, must, it is said, have been totally unfit to maintain the life of animals. The supposition then is, that through the vast preponderance of the vegetable kingdom, for many ages, on the surface of the earth, the carbonic acid was gradually reduced in proportion down to its present small measure; and that the carbon so abstracted from the carbonic acid is that which now forms so large a proportion of the bodies both of plants and animals, and so large a proportion of the soil of the earth. And now that the animal kingdom has begun to preponderate, and a greater proportion of carbonic acid is produced by the respiration of animals than is decomposed by the food of plants, this change will go on increasing, until at last the atmosphere will become again unfit for the support of animals, owing to the great accumulation of carbonic acid. The determination of this question involves several considerations. It is true that the forests which covered the earth in ancient times are fast disappearing; but it is also true that these forests are replaced by cultivated crops. Shall we then say that if all the arable parts of the earth become covered with crops, those crops will not destroy as much carbonic acid as the ancient forests? And if this be the case, then the carbonic acid will not undergo any material increase. One thing is certain, that the animal kingdom, as respects its constituent carbon, can only increase at the expense of the vegetable kingdom; so that, while there must remain the same quantity of carbon at the earth's surface, a larger proportion will certainly be contained in the animal kingdom than in the vegetable, owing to the destruction of the ancient forests. But if the whole quantity of carbon contained jointly in the crops, and in the animal kingdom, and in the soil, remains equivalent to the quantity now in those three conditions, no change can take place in the quantity of the carbonic acid in the atmosphere. Again, it is perhaps impossible that the animal kingdom can increase so fast as to deteriorate the air much, when it is considered, that the only part of the animal kingdom that can be regarded as on the increase, is man himself, and the animals subservient to him.

An easy answer to the difficulty which has been here raised is, that by computation, from very probable data ("Edinburgh New Philosophical Journal," July, 1845), the conversion of the whole carbon of the soil, and of living plants and animals, into carbonic acid, would not more than double the small proportion of that gas existing at present in the atmosphere.

The connection of pestilential diseases with deficiency of the means of subsistence has too little engaged the attention of legislators. It is true there are certain diseases of an epidemic character, such as small-pox, measles, scarlet fever, which prevail even among the best fed orders of society. It is undeniable, however, that even these epidemics are far more fatal when joined with an insufficiency of food. In modern times, it is hardly possible to conceive the ravages which, in the earlier ages, epidemics inflicted upon the human race. At those periods, agriculture had made but very slender progress; and what surprises us is not so much that the nations of Europe suffered from such diseases as that they did not suffer even more. Were the same circumstances which so often prevailed in those countries again renewed in the present crowded state of many of the countries of Europe, the devastation would be far greater than even we find to be recorded of those times. Great sanitary improvements have taken place in all the countries of Europe, defective as that kind of legislation still is. But when the rapid increase of our great towns, without any previous means being secured for their proper drainage and ventilation is considered, physiology cannot too loudly pro-claim, not only that virulent epidemic diseases may arise under such circumstances, but extend their ravages even beyond the limits of those localities in which imperfect regulations prevail.

As respects the general maintenance of health, physiology supplies many important precepts; although nature in this respect has hardly left man to be governed by physiology. Hunger forces man to the highest activity for the preservation of his life; and under this appetite, aided by common sense, a body of popular dietetic rules has arisen, the habitual observation of which, more from imitation than from reflection, serves to preserve individuals in health. It is only by seeking a variety of food that man is sure to obtain all the chemical constituents required for the maintenance of his bodily frame. We have already shown that each of the simple elements, of which the human body is composed, is continually passing out by various excretory channels; and that, unless replaced, nutrition becomes deficient, and the function of that part which fails to receive its just supply is necessarily impaired. It doubtless often happens that the digestive powers are too feeble to extract the substances required from one kind of food, while they may be sufficient to obtain them from another. The desire of a variety of food, then, is plainly a species of instinct implanted in man for the purpose of securing the perfect nutrition of the animal frame.

Physiology is the handmaid of medicine; and in its largest sense, it even includes pathology. The relation between physiology proper and pathology has no parallel in other departments of knowledge. In physical science, as there is no death, so there is no disease. The mere derangement of machinery invented by man is very different from the state of disease in physiological nature. But not to waste time on a subject scarcely relevant to our present purpose, it is at least manifest that in the derangement of machines there is not, as in the case of disease, a power inherent in them to rectify and to restore themselves to their former state of efficiency. Such a power, however, is what characterizes pathology in particular. It is sometimes said that in meteorology, storms and tempests, as contrasted with calm weather, are the diseases of the atmosphere. But even in this department there is no close analogy between the two cases. A mere disturbance of the equilibrium of the atmosphere, on which every sudden change of the weather depends, bears but a very remote analogy to the pathological states to which living nature, and in particular the human nature, is subject. But when we come to chemical science—to that science which treats of the combinations of bodies, and of their actions and reactions upon each other, then we perceive at once how totally different physical nature (and under chemistry the whole of physical nature falls) is from organic nature, in respect to that class of phenomena which constitute the special department of physiology termed pathology. In chemical nature there is no individuality, unless, rejecting the idea of the infinite divisibility of matter, we pronounce each atom of a chemical substance to possess an individuality. And this view at present supplies us with the best and most correct notion of the grand distinctions existing between physical and physiological nature. The individuals, then, of which chemistry treats are mere atoms of simple bodies—every massive simple body is merely a group of individual atoms—each of these atoms is, in a very definite sense, an independent individual; it possesses all the properties which belong to the mass or aggregate in which it is seen to exist; by being separated from that mass it loses nothing; in the present system of things it is imperishable; it knows no decay, it knows no fatigue, it knows no exhaustion of its properties, it knows no dissolution or death. From its first creation to the time when the Eternal shall pronounce the fiat of its extinction, it knows no change of character. How different are the terms in which the individual falling under physiological nature must be spoken of! Here the individuality lies in the peculiar aggregation of a great mass of different particles; no two individuals are exactly alike; no individual is exactly like itself even for a moment; there is a perpetual change; even the very atoms which compose the individual are continually disappearing—the form remains, while the substance is continually changing; there is an unceasing rise, progress, decay, and dissolution; the dissolution, however, does not lie in the loss of the constituent substance, but in the failure of the indispensable form. Here, then, lies the great distinction between the individuals of physiological nature and the individuals of physical nature. In physical nature each individual retains throughout all time its proper identity; is always the same under the same circumstances; associates itself in innumerable ways with other individuals like itself, but never loses its own peculiar properties and character. The individual of physiological nature retains its identity through the best part of a century, while the substance which renders it a sensitive body is continually undergoing a change. It retains no identity of mere matter, but only an identity of form and spirit. An atom of carbon now exists in the crayon of the artist; now floats about the atmosphere from pole to pole in a new combination; now enters into the constitution of some vegetable nature; now is a component part of some animal frame; now is cast forth again into the atmosphere, and thus enjoys an immortality of existence altogether free from the laws of accident, disease, or death.

Physiology is the truest guide in medicine; and man is by nature a physician—is an observer of diseases, and of the means under which, whether by design or accident, diseases have disappeared. Medicine in its ruder states exhibits a few individuals who have not only been themselves diligent observers of diseases and remedies, but also inquirers into the experience of others. There are certain parts of medicine and surgery open to common observation without much risk of deception or error. But as long as a man is ignorant of physiology he is groping in the dark; he is deceived at every step; he mistakes mere successive occurrences for events standing in the relation of cause and effect; and, if he be of a rash character, or even only of an ardent mind, he is very apt by his interference to aggravate rather than promote the cure of disease. When physiology has made some progress—that is to say, when the spirit in which the Creator willed the actions of living nature to take place has been apprehended—then men begin to discriminate the shades of disease with more accuracy, and to observe with less risk of error what remedies have contributed to a cure. Till physiology made such progress, medicine was overburdened with precepts rashly inferred by unskilful observers.

The last great use of the science of physiology to which we shall advert, is its intimate connection with that science which points out the evidence of design in nature; and it is in the organic world chiefly that we find such evidences.

It is a great error to suppose that human knowledge is confined to determining the laws according to which phenomena occur. Those who study the evidence of design in the universe, are sometimes reproached with deviating from the proper purpose of philosophy. They are told that philosophy has nothing to do with the origin of things; but only with the laws which regulate the phenomena which man is capable of observing. But this is an assumption purely gratuitous. It is quite true that man in early ages made small progress, attempting to find out the purpose for which everything that exists was made. It is also true that Bacon described final causes as barren of effect. But if we find that the knowledge of nature, and particularly of organic nature, has now advanced so far that the study of the purposes for which organic parts were made, leads to the elucidation of the science; and that the st final causes is no longer that barren pursuit which it was in Bacon's time; then we entitled to repel this reproach, and to consider on what grounds it is affirmed that ma knowledge must be confined within the investigation of the mere laws of phenomena and not extend to the study of the purposes to which the various forms of organic structure are subservient. There is manifestly no other ground for affirming that human inquiry should be confined to the study of the laws according to which phenomena take place, than the argument that this is the only way in which human knowledge can be extended. Those who so argue altogether ignore physiology. The most ancient expression for physiology is the *usus partium*, that is to say, the use of the parts of the body. What does this mean? Surely it signifies that the study of the parts of the animal frame and of the vegetable structure, leads to a knowledge of the design with which the animal or the plant was made after that fashion. The discovery of the use of a part is not only a new step in physiology, but the observation of the relation between the structure of a part and its function is a fact in evidencing design. Till that discovery is made the human mind remains altogether unsatisfied with the most minute knowledge of the mere structure. The extent to which this is true will at once appear from the species of shame with which anatomists and physiologists point out those organs in the animal frame, the distinct use of which has not yet been discovered. There are such organs in the body, for example the spleen, the thyroid gland over the upper part of the windpipe, the supra-renal capsules, and some parts in the anatomy of the embryo. The most persevering efforts are continually made to connect the structure of such parts with some definite use in the living body. What are these efforts but the most conclusive confession that the human mind cannot rest satisfied with the mere knowledge of the size, the form, the minute internal structure of a part, unless it be able to conceive with what purpose that part was placed in the situation which it occupies?

The character of human knowledge is not to be sought in the speculations of philosophers. A far truer standard of the character of human knowledge will be obtained from the common principles which pervade the minds of mankind at large. It is vain to attempt to extinguish man's curiosity to know why a part was so constructed, or why it was placed in the situation which it occupies. Such inquiries are as natural to him as the desire to discover the laws which regulate the succession of phenomena. It is not to be supposed, however, that man has been gifted with powers sufficient to discover the whole plan on which organic nature is constructed. He need not expect to become able to explain the particular purpose of every variety of structure which he discovers in the animal and vegetable kingdom. It is long since physiology reached the truth that, in some species, there are parts of structure which do not seem to have any special office, or any special bearing on peculiar habits. It is long since physiology became acquainted with what are termed rudimentary structures, both in the imperfect and in the mature state of individuals. The simplest example of a rudimentary organ is the mamma in the male of the human race. It performs no office. The disciple of a positive philosophy points to those organs, and sneeringly asks how this is to be reconciled with our doctrines. But, suppose all the rudimentary organs which are known, and all the peculiarities of structure in animals, which seem to serve no useful purpose in relation to the habits of the animal, were deducted; what an infinitesimal proportion would the total amount of these make as compared with the vast array of organs with distinct uses, left to constitute the evidence of design! The disciple of a positive philosophy sarcastically asks, of what use it is to the whale to have the bones corresponding to each of the bones in the human arm, or upper extremity? Here we answer by referring him to his favourite term, LAW: it is a law that the great orders of animals are developed upon one grand type. This law we discover by observation; it is a part of inductive science; it has nothing to do with design. But, having ascertained this law of development according to the type, we then discover that that type is made to bend into a conformity with the particular habits and usages of each species.

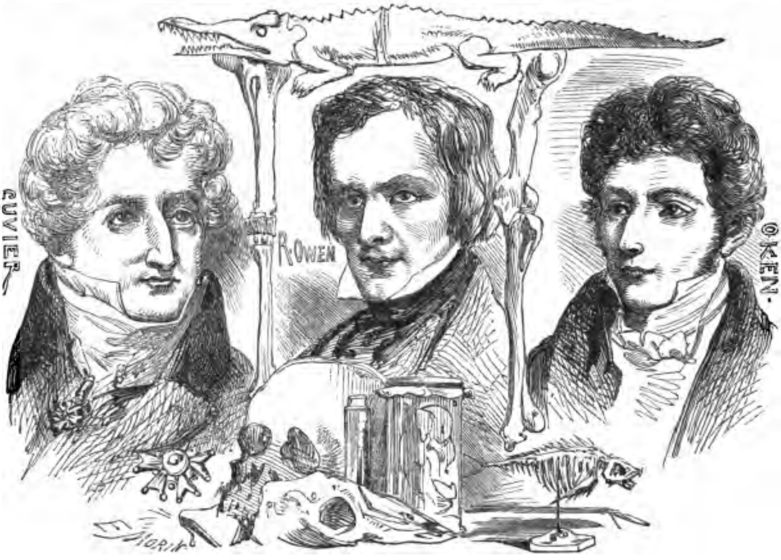
Here, then, is a great fact; and notwithstanding the law, in obedience to which the unwieldy whale, with its short fin-like arms, has in those arms a bone corresponding to every one of those in the human upper extremity, yet are these analogies of the human bones so modified as in the most perfect manner to become subservient to the different uses to which this animal applies its anterior extremity. The disciple of the positive philosophy no doubt says—surely the fore-paw of a whale might have been constructed on a more simple plan, to answer all the uses to which it is subservient. But does this answer shake the foundations of the evidences of design? Before his arguments become of any avail, he must show that the fore-paw of the whale is unfit for the purposes required by the habits of that animal, because it is framed on the type of the human upper extremity. We do not pretend to say why it has pleased the AUTHOR OF NATURE to establish that law according to which the skeleton of mammals conforms to a certain type; but we do affirm that the AUTHOR OF NATURE, having restricted His creative power within the limits of that type, has displayed incontrovertible evidence of design in adapting the type of the human arm to the form of the fore-paw of the whale, in conformity with the uses which that part has to perform.

Such, then, is the kind of difficulty which presents itself in our reasonings upon design. The physiologist should never forget that his subject falls under the laws of inductive science, in as far as these are applicable to it; and he should never permit the disciple of a positive philosophy to refuse him the alternative of so regarding it, or considering the discovery of the fitness of means to an end as a new step in its progress.

A very remarkable feature in physiological nature is, that, after all, each individual, though composed of materials derived from mineral nature, is not dependent for his individuality and identity on the continued presence of that same aggregate of mineral substances. At every moment the materials of which a human being is composed are passing away, and giving place to new materials derived from without. In a short period of time, the substance of his body is entirely changed, yet his individuality, his identity, his personality remain. He is the same, and yet different. He is no longer the same matter; but he is the same man. The man is therefore something different from matter. Let the disciple of the positive philosophy expound this to us; if everything be material—if all the phenomena of the organic world be the result of internal laws belonging to material substances, what is it that represents man throughout his long life, notwithstanding the perpetual change of the matter which at any one moment composed his bodily frame? Man surely is something different from matter; he is a thinking spirit, and one of the earliest of his thoughts is to refer the changes which he sees taking place around him to Infinite Power, and to recognise in the accommodation of means to ends, the inherent design of Infinite Intelligence.

Truly did Galen say—"The study of physiology is a hymn in honour of the Deity."

THE EDITOR.



THE PRINCIPAL FORMS OF THE SKELETON.

Principles of Osteology.—The original substance of animals consists of a fluid with granules and cells. In the course of development tubular tracts are formed, some of which become filled with "neurine" or nervous matter; others with "myonine" or muscular matter; other portions are converted into glandular substance: a great proportion of the rest of the primordial matter forms "cellular substance." This substance, in many animals, becomes hardened, in certain parts of the body, by earthy salts. When those salts consist chiefly of phosphate of lime, the tissues called "osteine," or bone, and "dentine," or tooth, are constituted, between which the chief distinction lies in the mode of arrangement of the earthy particles, in relation to the maintenance of a more or less free circulation of the nutrient juices through such hardened or calcified tissues. In bone certain canals are left, of a calibre sufficient for the passage of capillary blood-vessels through the tissue. Still more minute tubes, sometimes expanding into cell-like cavities, are established for the slower percolation of the colourless fluid of the blood, called "plasma," or "liquor sanguinis." In true or hard dentine provision is made, by fine tubes, for the passage of plasma through its substance; but the red particles of the blood are excluded.

True osteine and dentine are peculiar to the highest division or province of the Animal Kingdom, which province has been termed "Vertebrata," from the prevalent disposition of the osseous matter in successive groups of more or less confluent bones called "vertebræ." (From *verto*, I turn; these being the parts on which the body bends or rotates.)

Before entering upon the disposition of the bony matter, a few words may be premised as to the composition of that matter in the different classes of Vertebrata. These classes are four:—Fishes, Reptiles, Birds, and Mammals, which latter class includes the hair-clad beasts, commonly called quadrupeds, with the naked whales, and human kind. Fishes have the smallest proportion, birds the largest proportion, of the earthy matter in their bones. The animal part in all is chiefly a gelatinous substance.

PROPORTIONS OF EARTHY OR INORGANIC, AND OF ANIMAL OR ORGANIC, MATTER IN THE BONES OF THE VERTEBRATE ANIMALS.

FISHES.

	Salmon.	Carp.	Cod.
Organic	60·62	40·40	34·30
Inorganic	39·38	59·60	65·70
	100·00	100·00	100·00

REPTILES.

	Frog.	Snake.	Lizard.
Organic	35·50	31·04	46·67
Inorganic	64·50	69·96	53·33
	100·00	100·00	100·00

MAMMALS.

	Porpoise.	Ox.	Lion.	Man.
Organic	35·90	31·00	27·70	31·03
Inorganic	64·10	69·00	72·30	68·97
	100·00	100·00	100·00	100·00

BIRDS.

	Goose.	Turkey.	Hawk.
Organic	32·91	30·49	26·72
Inorganic	67·09	69·51	73·28
	100·00	100·00	100·00

From the above table it will be seen that the bones of the fresh-water fishes have more animal matter, and are, consequently, lighter than those of fishes from the denser element of sea-water; and that the marine mammal called porpoise differs little from the sea-fish in this respect. The batrachian frog has more animal matter in its bones than the ophidian or saurian reptiles, and thereby, as in other respects, more resembles the fish. Serpents almost equal birds in the great proportion of the osseous salts, and hence the density and ivory-like whiteness of their bones.

The chemical nature of the inorganic or hardening particles, and of the organic basis of bone, is exemplified in the subjoined Table, including a species of each of the four classes of Vertebrata:—

CHEMICAL COMPOSITION OF BONES.

	Hawk.	Man.	Tortoise.	Cod.
Phosphate of lime, with trace of fluate of lime	64·39	59·63	52·66	57·29
Carbonate of lime	7·03	7·33	12·53	4·90
Phosphate of magnesia	0·94	1·32	0·82	2·40
Sulphate, carbonate, and chlorate of soda	0·92	0·69	0·90	1·10
Glutin and chondrin	25·73	29·70	31·75	32·31
Oil	0·99	1·38	1·34	2·00
	100·00	100·00	100·00	100·00

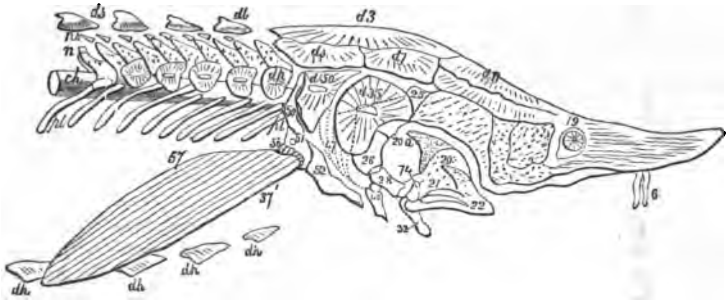
Bony matter is very variously disposed in the bodies of vertebrate animals. The sturgeon, the crocodile, and the armadillo are instances of its accumulation upon or near the surface of the body; and hence the ball-proof character of the skin of the largest of these mailed examples. The most constant position of bone is around the central masses of the nervous and vascular systems, with rays thence extending into the middle of the chief muscular masses, forming the bases of the limbs. Portions of bone are also developed to protect and otherwise subserve the organs of the senses, and in some species are found encasing mucus-ducts, and buried in the substance of certain viscera—as, *e. g.*, the heart in the bullock and some other large quadrupeds. Strong membranes, called "aponeurotic," and certain leaders or tendons, become bony in some animals; as, *e. g.*, the "tentorium" in the cat, the temporal fascia in the turtle, the leaders of the leg-muscles in the turkey, the nuchal ligament in the mole, Fig. 41, *u*, and certain tendons of the abdominal muscles of the kangaroo, which, so ossified, are called the "marsupial bones." Fig. 44.

For a clear and intelligible view of the osseous system in general, it has become requisite to make a primary classification of its parts according to their prevalent position, as in the cases above cited. The superficial or skin-bones constitute the system of the "dermo-skeleton" (from the Greek *derma*, skin, and *skeleton*); the deep-seated bones, in relation to the nervous axis and locomotion, form the "neuro-skeleton" (Gr. *neuron*, nerve, and *skeleton*), the bones connected with the sense-organs and viscera form the "splanchno-skeleton" (Gr. *splagchnon*, viscus, or inward part, and *skeleton*); those developed in tendons, ligaments, and aponeuroses, the "sclero-skeleton" (Gr. *scleros*, hard, and *skeleton*). These technical terms may seem harsh, and sound strange to those commencing the study of the structure of animals, but the most complex product of creation cannot be comprehended without terms expressive of the results of the classification and generalization of the manifold phenomena it offers to the contemplative student.

In the arrangement of the parts of the dermo-, splanchno-, and sclero-skeletons, no common pattern is recognisable. One can discern a definite end or purpose gained by the positions those terms indicate of certain bony plates, cases, or rods, and the special relation of such to the habits and well-being of the creatures manifesting them; but the diversity in the number, size, shape, and relative position of such dermal bones and visceral bones seems interminable.

The head of the sturgeon, Fig. 1, is defended by a case of superficial bony plates, *d* 3, *d* 7, *d* 11, &c., and the body by five longitudinal rows of similar plates—one extending along the mid-line of the back, *ds*, *ds*, one along each side of the body, *dp*, *dp*, and two along the belly, *dh*, *dh*, between the fins called "pectoral," 57, and

Fig. 1.

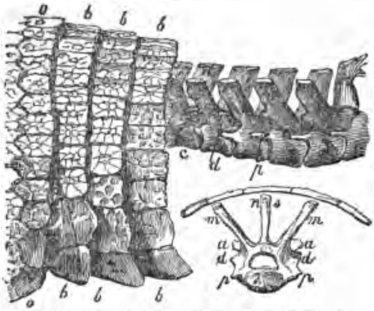


DERMO- AND NEURO-SKELETONS—STURGEON (*Acipenser Sturio*).

"ventral." The observations of the Ichthyologist, or of those concerned in the capture of the sturgeons for the sake of their air-bladder, of which the most valuable isinglass consists, show us how well the external defensive armour of these fishes is adapted to their mode of life. The sturgeons may be called the scavengers of the great rivers which they frequent: they habitually swim low, and grovel along the bottom, turning up the mud and sand with their pig-like snout, testing the disturbed matter with their feelers, 6, and feeding in shoals, on the decomposing animal and vegetable substances which are carried down with the debris of the continents drained by those rapid currents; thus they are ever busied reconverting the substances, which otherwise would tend to corrupt the ocean, into their own living organized matter. These fishes are, therefore, duly weighted by a ballast of dense dermal, osseous plates—not scattered at random over their surface, but regularly arranged, as every seaman knows how ballast should be, in orderly series along the middle and sides of the body. The protection against the logs and stones hurried along their feeding-grounds, which the sturgeons derive from their plate-armour, renders needless the ossification of the immediate case of the brain and spinal marrow, and consequently all the parts of the neuroskeleton, *ch*, *pl*, *n*, *ns*, remain in the flexible, elastic, gristly state; the weight of the dermoskeleton requiring that the other systems of the skeleton should be kept as light as might be compatible with its defensive and sustaining functions. This view of the final purpose of the dermal bony plates in the existing sturgeons affords some insight into the habits and conditions of existence of the similarly mailed extinct fishes which abounded in the seas of the secondary periods of the geological history of this planet. In most of these fishes, as in the sturgeons, the dermal bones are coated externally with a much harder material, resembling enamel, and such fishes have accordingly been termed "ganoid," from the Greek word "ganos," signifying brightness. The ganoid plates in those extinct fishes are usually more close-set, overlapping each other, and being fastened together like tiles, by a peg of one entering a socket in the next, and reciprocally. Only two genera of fishes are now known to exhibit this beautiful arrangement of the dermal bones, viz., the *polypterus* of the Nile, and the *lepidosteus* of the Ohio, and other great rivers of North America.

In the armadillo the dermal bones, Fig. 2, *o b*, are small, polygonal, usually five- or six-sided, smooth on their inner surface, which rests on the soft subcutaneous layer of cellular tissue, variously sculptured on the outer and exposed side, but with a pattern constant in, and characteristic of, each species. They are united together at their thick margins by rough or "sutural" surfaces, and resemble a tessellated pavement. The trunk is protected by a large buckler of this bony armour; the head is defended by a casque of the same; and the tail is encased in a sheath of similar interlocked ossicles. To allow of the requisite movements of the trunk in the small existing armadillos, which, when attacked, roll themselves into a ball, from three to nine transverse rows of the dermal bones, *b b*, are interposed, having a yielding elastic junction with each other, and with the anterior, *o o*, and posterior fixed, and larger, parts of the trunk-armour; and by this modification the head and limbs can be withdrawn beneath the armour, when its parts are pulled together by the strong cutaneous muscles into a hemispheric form. In South America, to which continent the armadillos are peculiar, remains of gigantic quadrupeds, similarly defended, have been discovered in the more recent tertiary deposits; but in these colossal armadillos (*Glyptodon*) the trunk-armour was in one immovable piece, covering the back and sides, and was not divided by bands. Besides the defence which such a modification of the integuments would afford against the attacks of predatory animals, the armadillos and glyptodons habitually frequenting the great forests of South America may have been protected by the same hard, arched covering from falling timber.

Fig 2.



PORTIONS OF DERMO- AND NEURO-SKELETONS—ARMADILLO (*Dasypus tricinctus*).

Such are some of the instances of the structure and uses of the dermoskeleton in the vertebrate province. The development of this system of the skeleton is not dependent on the grade of organization, for we find it in the highest and in the lowest classes; nor does a great amount of osseous matter in the skin necessarily involve a small amount or absence of the same matter in the deeper-seated skeleton; for all the parts of this system of bones, *a, c, d, m, ns*, are as well developed and as well ossified in the armadillos as in the quadrupeds which are covered by hair. The different states of the neuroskeleton in the sturgeon and armadillo are explicable only with reference to the different media and other conditions under which the two vertebrates were destined to exist.

In no species and in no system of the skeleton are bones a primary formation of the animal: they are the result of transmutations of pre-existing tissues, as substances composing animal bodies—*e.g.*, nerve, muscle, membrane, &c.—are called. The inorganic salts, defined in the tabular view of the composition of bone, pre-exist in the blood, in the albumen of the egg of the oviparous vertebrates, and in the milk which nourishes the new-born mammal.

The primitive basis, or "blastema," of bone is a subtransparent glairy matter, containing a multitude of minute corpuscles. It progressively acquires increased firmness—sometimes assumes a membranous or ligamentous state, sometimes a gristly state, before its conversion into bone. Its assumption of the gristly state is attended by the appearance in it of numerous minute nucleated cells. As the gristle or "cartilage" hardens, these cells increase in number and size, and are aggregated in rows at the part where ossification is about to begin. These rows, in the cartilaginous basis of long bones, are vertical to its ends—in that of flat bones they are vertical to the peripheral edge. The nucleated cells are the instruments by which the earthy particles are arranged in order; and in bone, as in tooth, there may be discerned, in this predetermined arrangement, the same relation to the acquisition of strength and power of resistance, with the greatest economy of the building material, as in the disposition of the beams and columns of a work of human architecture.

Osteine, so formed, is arranged in thin plates, concentrically around the vascular canals, around the entire circumference of the long bones, and in interrupted plates, connecting together the walls of the vascular canals, so as often to give rise to a reticular disposition of the bony substance.

In fishes the bones continue to grow throughout life, and their periphery, whether in the flat bones of the head which overlap each other, or the thicker bones that interlock, is cartilaginous or membranous, and the seat of progressive ossification. The long bones of most reptiles retain a layer of ossifying cartilage beneath the terminal articular cartilage; and growth continues at their extremities while life endures. Some of the long bones in frogs, birds, and most of those in mammals, have their ends distinct from the body or shaft of the growing bone, these separately ossified ends being termed "epiphyses:" the seat of the active growth of the shaft is in a cartilaginous crust at the ends supporting the epiphyses; when these coalesce with the shaft, growth in the direction of the bones' axis comes to an end; but there is a slower growth going on over the entire periphery of the bone, which is covered by a membrane, called the "periosteum." In this membrane, the vascular system of a bone, except the vessel supplying the marrow-cavity, undergoes the amount of subdivision which reduces its capillaries to dimensions suited for penetrating the pores leading to the vascular canals.

Thus bone is a living and a vascular part, growing by internal molecular addition and change, and having the power of repairing fracture or other injury. The shells and crusts of molluscous and crustaceous animals are unvascular; they grow by the addition of layers to their circumference, may be cast off when too small for the growing body, and be reproduced of a more conformable size. When fractured, the broken parts may be cemented together by newly superadded shell-substance from without; but are not unitable by the action of the fractured surfaces from within.

Extension of parts, however, is not the sole process which takes place in the growth of bone; to adapt a bone to its destined office changes are wrought in it by the removal of parts previously formed. In fishes, indeed, we observe a simple unmodified increase. To whatever extent the bone is ossified, that part remains, and consequently most of the bones of fishes are solid or spongy in their interior, except where the ossification has been restricted to the surface of the primary gristly mould. The bones of the heavy and sluggish turtles and sloths, of the seals, and of the whale-tribe, are solid. But in the active land quadrupeds, the shaft of the long bones of the limbs is hollow, the first formed osseous substance being absorbed, as new bone is being deposited from without. The strength and lightness of the limb-bones are thus increased after the well-known principle of the hollow column, which Galileo, by means of a straw picked up from his prison floor, exemplified, in refutation of a charge of Atheism brought against him by the Inquisition. The bones of birds, especially those of powerful flight, are remarkable for their lightness. The osseous tissue itself is, indeed, more compact than in other animals; but its quantity in any given bone is much less, the most admirable economy being traceable throughout the skeleton of birds, in the advantageous arrangement of the weighty material. Thus, in the long bones, the cavities analogous to those called "medullary" in beasts, are more capacious, and their walls are much thinner; a large aperture, called the "pneumatic foramen," near one end of the bone, communicates with its interior, and an air-cell, or prolongation of the lung, is continued into and lines the cavity of the bone, which is thus filled with rarefied air instead of marrow. The extremities of such air-bones present a light open net-work, slender columns shooting across in different directions from wall to wall, and these little columns are likewise hollow.

The enormous beak of the hornbill, which seems at first sight to constitute so grave an impediment to flight, forms one enormous air-cell, with very thin bony walls; and in this bird, in the swifts, and the humming-birds, every bone of the skeleton, down to the last joints of the toes, is permeated by hot air. The opposite extreme to the above members of the feathered class is met with in the terrestrial apteryx (wingless bird of New Zealand), and in the aquatic penguin; in both of which, not any bone of the skeleton receives air. Intermediate gradations in the extent to which the skeleton is permeated by air occur in different birds, and in relative proportion to their different kinds and power of flight.

In the mammalian class, the air-cells of bone are confined to the head, and are filled from the cavities of the nose or ear, not from the lungs. Such cells are called "frontal sinuses," "antrum," "sphenoidal" and "ethmoidal sinuses" in man. The frontal sinuses extend backwards over the top of the skull in the ruminant and some other quadrupeds, and penetrate the cores of the horns in oxen, sheep, and a few antelopes. The most remarkable development of air-cells in the mammalian class is presented by the elephant; the intellectual physiognomy of this huge quadruped being caused, as in the owl, not by the actual capacity of the brain-case, but by the enormous extent of the pneumatic cellular structure between the outer and inner plates of the skull-walls.

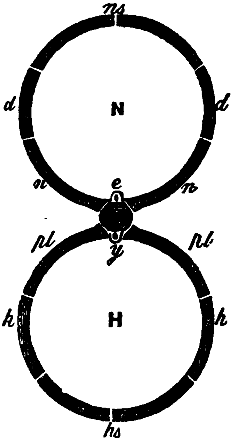
In all these varied modifications of the osseous tissue, the cavities therein, whether mere cancelli, or small medullary cavities as in the crocodile, or large medullary cavities as in the ox, or pneumatic cavities and sinuses as in the owl, are the result of secondary changes by absorption, and not of the primitive constitution of the bones. These are solid at their commencement in all classes, and the vacuities are established by the removal of osseous matter previously formed, whilst increase proceeds by fresh bone being added to the exterior surface. The thinnest-walled and widest air-bone of the bird of flight was first solid, next a marrow bone, and finally became the case of an air-cell. The solid bones of the penguin, and the medullary femur of apteryx, exemplify arrested stages of that course of development through which the pneumatic wing-bone of the soaring eagle had previously passed.

But these mechanical modifications do not exhaust all the changes through which the parts of a skeleton, ultimately becoming bone, have passed: they have been previously of a fibrous or of a cartilaginous tissue, or both. Entire skeletons, and parts of skeletons, of vertebrate animals exhibit arrests of these early stages of development; and this quite irrespective of the grade of the entire animal in the zoological scale. The capsule of the eye-ball, for example, in man, is a fibrous membrane; in the turtle, it is gristle; in the tunny, and most other fishes, it is bone. The skeletal framework of the little lancelet-fish (*Branchiostoma*) does not go beyond the fibrous stage of tissue-change.* In the sturgeon, skate, and shark, it stops at the gristly stage, and hence these fishes are called "cartilaginous." In most fishes, and all air-breathing vertebrates, it proceeds to the bony stage, with the subsequent modifications and developments above recited.

The main part of the skeleton—what may be termed the skeleton proper—consists of the neuroskeleton; and it is in the construction of this system that the most interesting and beautiful evidences of unity of plan, as well as of adaptation to end, have been discerned. The parts of the neuroskeleton are arranged in a series of segments, following and articulating with each other, in the direction of the axis of the body, from before backwards in brutes, from above downwards in man.

Each complete segment, called "vertebra," consists of a series of osseous pieces, arranged according to one and the same plan (Fig. 3), viz., so as to form a bony hoop, or arch, above a central piece, for the protection of a segment of the nervous axis, and a bony hoop, or arch, beneath the central piece, for the protection of a segment of the vascular system. The upper hoop is called the neural arch, N (Gr. *neuron*, nerve); the lower one, the "hæmal arch," H (Gr. *haima*, blood); their common centre is termed the "centrum," *c* (Gr. *kentron*, centre). The neural arch is formed by a pair of bones, called "neurapophyses," *n n* (Gr. for nerve and apophysis, a projecting part or process); and by a bone, sometimes cleft or bifid, called the "neural spine," *ns*; it also sometimes includes a pair of bones, called "diapophyses," *d d* (Gr. *dia*, across, or transverse, and apophysis). The hæmal arch is formed by a pair of bones called "pleurapophyses," *pl* (Gr. *pleuron*, rib, and apophysis); by a second pair, called "hæmapophyses," *h* (Gr. for blood, and apophysis); and by a bone, sometimes bifid, called the "hæmal spine," *hs*. It also sometimes includes parts, or bones, called "parapophyses" (Gr. *para*, transverse, and apophysis). Bones, moreover, are developed, which diverge as rays, from one or more parts of a vertebra.

Fig. 3.



TYPICAL VERTEBRA.—(IDEAL.)

The parts of a vertebra which are developed from independent centres of ossification are called "autogenous;" those parts that grow out from previously ossified parts are called "exogenous;" the autogenous parts of a vertebra are its "elements," the exogenous parts its "processes." No part, however, is absolutely autogenous throughout the vertebrate series, and some that are exogenous in most are autogenous in a few instances. The line cannot be strictly drawn; and, in classifying the parts of a vertebra, as of other parts of animals, or of entire animals, the systematist must be guided by general rules, to which there will ever be some exceptions.

The elements, or autogenous parts, of a vertebra are the centrum, *c*, the neurapophyses, *n*, the neural spine, *ns*, the pleurapophyses, *pl*, the hæmapophyses, *h*, and the hæmal spine, *hs*. The exogenous parts are the diapophysis (Fig. 5), *d*, the parapophysis (*ib.*) *p*, the zygapophysis (Fig. 6), *z* (Gr. *zugos*, junction, and apophysis), the anapophysis (Fig. 2), *a* (Gr. *ana*, backwards, and apophysis), the metapophysis (*ib.*), *m* (Gr. *meta*, between, and apophysis), the hypapophysis (Fig. 5), *y* (Gr. *hypo*, below, and apophysis), and the epapophysis (Fig. 4), *e* (Gr. *epi*, above, and apophysis). Of the autogenous parts, the neural spine is most commonly exogenous; of the exogenous parts, the parapophyses, diapophyses, and hypapophyses are sometimes autogenous.

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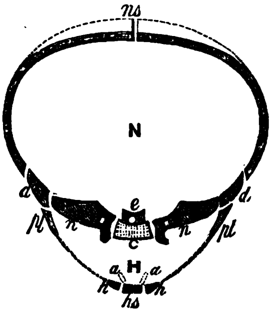
* The doctrine or study of this kind of development—the development of substance and texture, as contradistinguished from that of size and shape—is now termed "Histology," from the Greek *histos*, net or tissue, and *logos*, a doctrine or discourse.

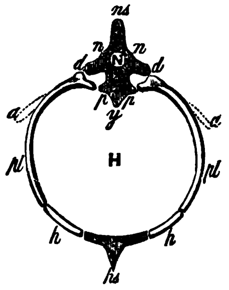
Vertebræ are subject to many and great modifications—*e. g.*, as to the number of the elements retained in their composition, as to the form and proportion of the elements, and even as to the relative position of the elements; but the latter modification is never carried to such a degree as to obscure the general pattern or type of the segment.

Fig. 4.



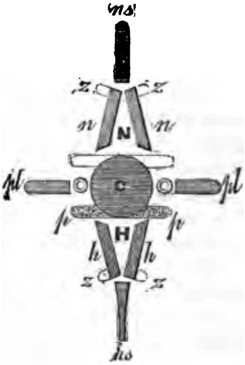
PARIETAL SEGMENT, OR VERTEBRA—MAN.

Fig. 5.



THORACIC SEGMENT, OR VERTEBRA—RAVEN.

Fig. 6.



TYPICAL VERTEBRA.

Sometimes, as in the example (Fig. 4) of the third segment of the human skeleton, the neural arch, N, is much expanded, the hæmal one, H, is contracted; and, in the expanded neural arch, the autogenous diapophyses, *d d*, are wedged between the neurapophyses, *n*, and the enormously expanded neural spine, *ns*. More commonly, as in the example from the raven's thorax (Fig. 5), the hæmal arch, H, is much expanded, the neural one, N, contracted; and in the expanded hæmal arch, the parapophysis, *p*, here exogenous, is wedged between the centrum, C, and the pleurapophysis, *pl*. Sometimes, again, as is exemplified in the tail of the crocodile and of many other animals, both neural and hæmal arches are alike contracted; the pleurapophyses, *pl*, being excluded from the latter, and standing out as continuations of the confluent diapophyses, *d*, and parapophyses, *p*. Such vertebræ deviate but little from the ideal type of the vertebra, under its less developed condition, as in Fig. 6. The segments are commonly simplified and made smaller as they approach the end of the vertebral column or axis, one element or process after another is removed, until the vertebra is reduced to its centrum, as in the subjoined diagram (Fig. 7), of the archetype vertebrate skeleton. In this scheme, which gives a side view of the series of segments or vertebræ, the nature of the principal modifications to which they are subject are indicated, at the two extremes of the series.

As the four anterior divisions of the great trunk of the nervous system are called, collectively, "brain," so the four corresponding segments of the osseous system are called "skull." The head, therefore, is not otherwise a repetition of the trunk, than in so far as each segment of the skull is a repetition or "homotype" of every other segment of the body; each being subject to modifications which may give it an individual character, without obliterating its typical features. So neither are the "arms" and "legs" repeated in the head in any other sense than as the cranial vertebræ may retain their "diverging appendages," 25, 37, 44, 53, *a*. The fore-limbs are actually such appendages, 53, of the occipital vertebra, 1, 3, 2, 51, 52, 59, which appendages undergo modifications closely analogous to those of the appendages of the pelvic segment, or "hind limbs," 65. And inasmuch as in one class the pelvic appendages, with their supporting hæmal arch, 63, *hs*, are detached from the rest of their segment, and subject to changes of position (Fig. 9), 63, 69; so also in other classes the appendages of the occipital segment are liable to be detached, with their sustaining hæmal arch, and to be transported to various distances from their proper centrum and neural arch, as in Fig. 21, Nos. 51, 53, 57.

The four anterior neurapophyses, 14, 10, 6, 2, give issue to the nerves, the terminal modifications of which constitute the organs of special sense.

The first or foremost of these is the organ of smell, 19, always situated immediately in advance of its proper segment, which becomes variously and extensively modified to inclose and protect it.

The second is the organ of sight, 17, lodged in a cavity or "orbit" between its own and the nasal segment, but here indicated above that interspace.

The third is the organ of taste, the nerve of which perforates the neurapophysis, 6, of its proper segment, called "parietal vertebra," or passes by a notch between this and

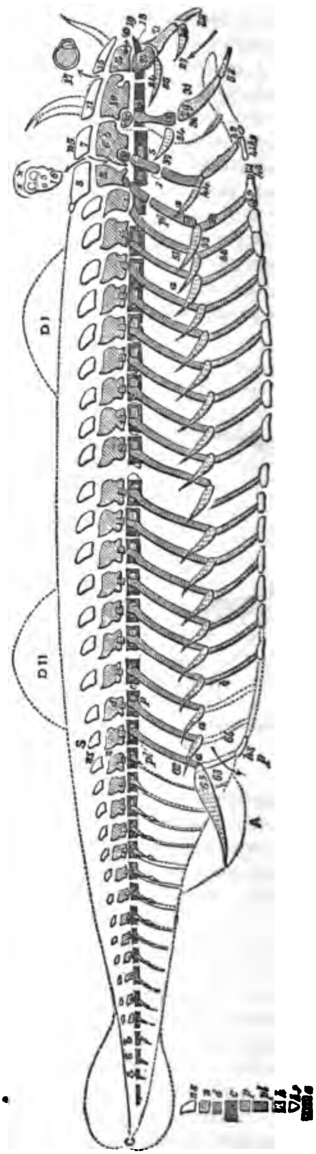


Fig. 7.—ARCHETYPE VERTEBRATE SKELETON.

the neurapophysis, 10, of the frontal vertebra, to expand in the organ, which is always lodged below, in the cavity called "mouth," and is supported by the hæmal spine, 41, *hs*, of its own vertebra.

The fourth is the organ of hearing, 16, indicated above the interspace between the neurapophysis of its own (occipital) and that of the antecedent (parietal) vertebra, in which it is always lodged; the surrounding vertebral elements being modified to form the cavity for its reception, which is called "otocrane." The jaws are the modified hæmal arches of the first two segments.

The mouth opens at the interspace between these hæmal arches; the position of the vent varies (in fishes), but always opens behind the pelvic arch, 8, 62, 63, *p*, when this is ossified.

Outlines of the chief developments of the dermoskeleton, in different vertebrates, which are usually more or less ossified, are added to the neuroskeletal archetype; as, *e. g.*, the median horn supported by the nasal spine, 15, in the rhinoceros; the pair of lateral horns developed from the frontal spine, 11, in most ruminants; the median folds, DI, DII, above the neural spines, one or more in number, constituting the "dorsal" fin or fins in fishes and cetaceans, and the dorsal hump or humps in the buffaloes and camels; similar folds are sometimes developed at the end of the tail, forming a "caudal" fin, C, and beneath the hæmal spines, constituting the "anal" fin or fins, A, of fishes.

The different elements of the primary segments are distinguished by peculiar markings:—

The neurapophyses by diagonal lines, thus— /////

The diapophyses by vertical lines—||||||

The parapophyses by horizontal lines—≡

The *centrum* by decussating horizontal and vertical lines— ▦

The pleurapophyses by diagonal lines— \\\\\

The appendages by dots— : : : : :

The neural spines and hæmal spines are left blank.

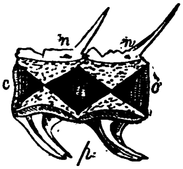
In certain segments the elements are also specified by the initials of their names:—

ns is the neural spine.
n is the neurapophysis.
pl is the pleurapophysis.
c is the centrum.
h is the hæmapophysis, also indicated by the Nos. 21, 29, 44, 52, 58, 63, 64.
hs is the hæmal spine.
a is the appendage.

The centrum is the most constant vertebral element as to its existence, but not as to its ossification. There are some living fishes, and formerly there were many, now extinct, in which, whilst the peripheral elements of the vertebra become ossified, the central one remains unossified; and here a few words are requisite as to the development of vertebræ.

The central basis of the neuroskeleton is laid down in the embryo of every vertebrate animal, as a more or less cylindrical fibrous sheath, filled with simple cells containing jelly. This fibro-cellulo-gelatinous column is called "notochord," Fig. 1, *ch* (Gr. *notos*, back; *chorda*, cord; in Latin, "chorda dorsalis"). The centrums, or "bodies of the vertebræ," as anthropotomists call them, are developed in and from the notochord. The bases of the other elements of the vertobra are laid down in fibrous bands, diverging from the notochord, and giving the first indication of the segmental character of the skeleton. At this stage the skeleton of the little fish called "lancelet" (*Amphioxus lanceolatus*) is arrested. These fibrous bands are next converted into cartilage, and the cartilage is in definite pieces in each segment, recognisable as "neurapophyses" (Fig. 1), *n*; "pleurapophyses" (*ib.*), *pl*; "neural spine" (*ib.*), *ns*—the centrums still remaining in their primitive state as the undivided notochord (*ib.*), *ch*. At this stage the skeleton of the sturgeon is arrested. The peripheral elements may be converted into bone, the central ones remaining as notochord, as in the protopterus, the lepidosiren, and many fossil fishes. But, more commonly, the next stage is the subdivision of the notochord into a series of separate centrums, corresponding with the pairs of neurapophyses and pleurapophyses—ossification of all the parts being more or less imperfect, as in the sharks and rays, which have thence been called "cartilaginous fishes." When the parts of the vertebræ have become more completely ossified, as in the fishes called "osseous," ossification is rarely so advanced as in the higher vertebrata. In most of these fishes, *e. g.*, a deep cavity is left at each end of the centrum (Fig. 8), *cc*, which cavity continues to be occupied by the liquefied gelatinous remains of the primitive notochord; and the characteristic of such element in a fish's skeleton is, that it is "biconcave." Of the minor amount of the earthy matter in the ossified parts of the skeleton of fishes, mention has been already made; and the consequent greater flexibility and elasticity of such bones may be readily tested by whoever will bend one of the long spines in the skeleton of a cod or turbot, and contrast its flexibility with that of the similarly-shaped long and slender bone (*pubis*, or *fibula*, *e. g.*), which he may find in the Christmas turkey that follows in the feast.

Fig. 8.



SECTION OF VERTEBRÆ—FISH.

Two or more contiguous vertebræ are frequently subjected to the same kind of modification, either by way of excess or defect, and such groups of modified segments have received special names; such, for example, as "skull" (*cranium*), "neck" (*cervix*), "chest" (*thorax*), "pelvis," and "tail" (*cauda*); and these terms are reciprocally applied, when modified as adjectives, to the individual vertebræ so grouped together, and which are called "cranial vertebræ," "cervical vertebræ," "dorsal" or "thoracic vertebræ," "sacral" or "pelvic vertebræ," and "caudal vertebræ."

Skeleton of the Fish.—In all fishes the extent of ossification is less than in the higher vertebrate classes. Only in the skull do we find all the elements of the typical segment represented by bone. In the trunk, *e. g.*, the hæmapophyses and hæmal spines never advance beyond the fibrous stage of tissue development.

Four segments enter into the composition of the skull of fishes, answering to the first four in the archetype (Fig. 7), and they combine to constitute the bony framework of a head, larger in proportion to the trunk than in any other class of animals. The skull (Fig. 9), 3, 52, *br*, forms a cone, whose base is vertical, directed backwards, and joined to the trunk without an intervening neck, and whose sides are commonly three in number, one superior, and two lateral and inferior. The cone is shorter or longer, more or less compressed or squeezed from side to side, more or less depressed or flattened from above downwards, with a sharper or blunter apex, in different species of fishes. The base of the skull is perforated by the hole, called "foramen magnum," for the exit of the spinal marrow; the apex is more or less widely and deeply cleft transversely by the aperture of the mouth; the eye-sockets or "orbits," *or*, are lateral, large, and usually with a free and wide intercommunication in the skeleton; the two vertical fissures behind are called "gill-slits," or branchial or opercular apertures, and there is a mechanism, like a door, 34, 35, 36, for opening and closing them. The mouth receives not only the food, but also the streams of water for respiration (indicated by the arrow, *br*), which escape by the gill-slits. The head contains not only the brain and organs of sense, but likewise the heart and breathing organs. The inferior or "hæmal" arches are greatly developed accordingly, and their diverging appendages support membranes that can act upon the surrounding fluid, and are more or less employed in locomotion: one pair of these appendages, P, 57, answers, in fact, to the fore-limbs in higher animals, and their sustaining arch, 51, 52, in many fishes, also supports the homologues of the hind-limbs, V, 69. Thus brain and sense-organs, jaws and tongue, heart and gills, arms and legs, may all belong to the head; and the disproportionate size of the skull, and its firm attachment to the trunk, required by these functions, are precisely the conditions most favourable for facilitating the course of the fish through its native element.

It may well be conceived, then, that more bones enter into the formation of the skull in fishes than in any other animals; and the composition of this skull has been rightly deemed the most difficult problem in Comparative Anatomy. "It is truly remarkable," writes the gifted Oken, to whom we owe the first clue to its solution, "what it costs to solve any one problem in Philosophical Anatomy. Without knowing the *what*, the *how*, and the *why*, one may stand, not for hours or days, but weeks, before a fish's skull, and our contemplation will be little more than a vacant stare at its complex stalactitic form."

To show *what* the bones are that enter into the composition of the skull of the fish; *how*, or according to what law, they are there arranged; and *why*, or to what end, they are modified, so as to deviate from that law or archetype, will next be our aim. These points, rightly understood, yield the key to the composition of the skull in all vertebrata, and they cannot be omitted without detriment to the main end of the most elementary essay on the skeletons of animals. The comprehension of the description will be facilitated by reference to Figs. 7 and 9; and still more if the reader have at hand the skull of any large fish.

In the cod (*Gadus morrhua* *), *e. g.*, it may be observed, in the first place, that most of the bones are, more or less, like large scales; have what, in anatomy, is called the "squamous" character and mode of union, being flattened, thinned off at the edge, and overlapping one another; and one sees that, though the skull, as a whole, has less freedom of movement on the trunk, more of the component bones enjoy independent movements. Before we proceed to pull apart the bones, it may be well to remark, that the principal cavities, formed by their co-adaptation, are the "cranium," lodging the brain and the organs of hearing; the "orbital," Fig 9, *or*, and the "nasal," *nl*, chambers; the buccal and branchial canals, *br*. Some of these cavities are not well defined. The exterior of the skull is traversed by five longitudinal crests, intercepting four channels which lodge the beginnings of the great muscles of the upper half of the trunk. The median crest is developed to an extreme height in some fishes, as, *e. g.*, the dolphin and light-horseman fish (*Ephippus*). The flat-fishes (turbot, sole, &c.) are remarkable for the unsymmetrical character of the skull, in consequence of both eyes being placed on one side of the head.

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* The skull of this fish, conveniently prepared for this examination, may be had of Mr. Flower, No. 22, Lambeth Terrace, Lambeth Road.

In the analysis of the cod's skull it is best to begin at the back part; for the segments of the skeleton deviate most from the archetype as they recede in position towards the two extremes of the body. After a little practice one succeeds in detaching the bones which form the back part or base of the conical skull, and which immediately precede and join those of the trunk; we thus obtain a "segment" or "vertebra" of the skull. If we next proceed to separate a little the bones composing this segment, we find those that were most closely interlocked to be in number and arrangement as follows:—Two single and symmetrical bones, and two pairs of unsymmetrical bones, forming a circle; or, if the lower symmetrical bone, which is the largest, be regarded as the base, the other five form an arch supported by it, of which the upper symmetrical bone is the key-stone.* This answers to the "neural" arch of the typical vertebra: the base-bone is the "centrum," *c;* the pair of bones, which articulated with its upper surface and pro-

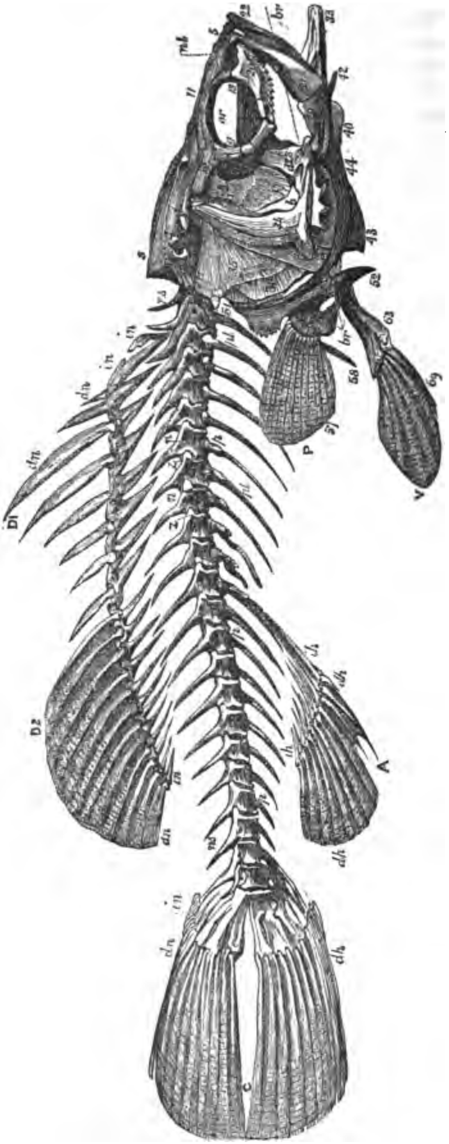

FIG. 9.—SEA-PERCH (*Lates*).

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[*] See my work "On the Archetype of the Skeleton," 8vo, 1848, p. 10, Fig. 1.

tected the hind division of the brain, form the "neurapophyses," *n;* the smaller pair of bones, projecting outwards, like transverse processes, are the "diapophyses," *d;* the symmetrical bone completing the arch, and terminating above in a long crest or spine, is the "neural spine," *ns.* It will be observed that the centrum is concave at that surface which articulates with the centrum of the first vertebra of the trunk: the opposite surface is also concave, but expanded and very irregular, in order to effect a much firmer union with the centrum of the next cranial segment in advance —great strength and fixity being required in this part of the skeleton, instead of the mobility and elasticity which is needed in the vertebral column of the trunk. It may be also observed that the "neurapophyses" are perforated, like most of those in the trunk, for the passage of nerves; that the diapophyses give attachment to the bones which form the great inferior or hæmal arch; and that the neural spine retains much of the shape of the parts so called in the trunk. Nevertheless, the elements of the neural arch of this hindmost segment of the skull have undergone so much development and modification of shape, that they have received special names, and have been enumerated as so many distinct and particular bones. The centrum, No. 1, is called "basioccipital;" the neurapophyses, No. 2, "exoccipitals;" the neural spine, No. 3, "superoccipital;" the diapophyses, No. 4, "paroccipitals." In the human skeleton all those parts are blended together into a mass, which is called the "occipital bone."

The entire segment, here disarticulated, in the cod-fish, is called the "occipital vertebra," and in it we have next to notice the widely-expanded inferior or hæmal arch. This consists of three pairs of bones. The first pair are bifurcate, and have two points of attachment to the neural arch, the lower prong, answering to what is called the "head of the rib," abutting upon the neurapophysis; the upper prong, answering to the "tubercle of the rib," articulating to the diapophysis. The second pair of bones are long and slender, and represent the body of the rib. The first and second piece together answer to the element called "pleurapophysis;" the third pair of bones are the "hæmapophyses;" these support diverging appendages consisting of many bones and rays. The special names of the above elements of the hæmal arch of the occipital vertebra are, from above downwards, "suprascapula," No. 50; "scapula," No. 51; "coracoid," No. 52. The inverted arch, so formed, encompasses, supports, and protects the heart or centre of the hæmal system; it is called the "scapular arch." There are animals—the gymnothorax and slow-worm, *e. g.*—in which this arch supports no appendage; there are fishes—the *protopterus, e. g.*, Fig. 32—in which it supports an appendage in the form of a single many-jointed ray, retaining the archetypal character, Fig. 7, No. 53. In other fishes, the number of rays progressively increase, until, in those called "rays" *par excellence,* they exceed a hundred in number, and are of great length, forming the chief and most conspicuous parts of the fish. The more common condition of the appendage in question is that exhibited in the species figured, Cut 9. So developed, it is called in Ichthyology the "pectoral fin:" otherwise and variously modified in higher animals, the same part becomes a fore-leg, a wing, an arm, and hand. Some of the special names, originally applied to the parts of the scapular appendage in man, are retained and applied to like parts in the pectoral fin of the fish. Of the two flat bones connecting the fin with the coracoid, the upper one is the "ulna," No. 54; the lower one the "radius," No. 55; the row of short bones joined with these are the "carpals," No. 56; the longer and more slender many-jointed rays answer to the parts called "metacarpals" and "phalanges" in the human hand. In the salmon there is a bone answering to the arm-bone or humerus, which is articulated to the middle of the back part of the coracoid by a transversely elongated extremity. It is also expanded at the distal end, where it articulates by cartilage with the ulna and radius. The ulna is a semicircular plate of bone perforated in the centre, and, besides its articulation with the humerus, the radius, and the ulnar carpals and metacarpal ray, it also directly joins the broad coracoid. The radius, after expanding to unite with the humerus, the ulna, and the radial carpals, sends a long and broad process downwards and inwards, which is united by ligament with its fellow and with the lower termination of the coracoid. A basis of adequate extent and firmness is thus insured for the support of the pectoral fins. The carpal bones of these fins are four in number, progressively increasing in length from the ulnar to the radial side of the wrist. The metacarpo-phalangial rays are thirteen in number; the uppermost or ulnar one being the strongest, and articulating directly with the ulna.

Proceeding to the next segment, in advance, in the cod-fish's skull, we find that the bone which articulated with the centrum of the occipital segment is continued forward beneath a great proportion of the skull. In quadrupeds, however, the corresponding part of the base of the skull is occupied by two bones; and if the single long bone in the fish be sawn across at the part where the natural suture exists in the beast, we have then little difficulty in disarticulating and bringing away with it a series of bones similar in number and arrangement to those of the occipital segment.

In the skeletons of most animals the centrums of two or more segments become, in certain parts of the body, confluent, or they may be connate; they form, in fact, one bone, like that, *e.g.*, which human anatomists call "sacrum." By the term "confluent" is meant the cohesion or blending together of two bones which were originally separate; by "connate," that the ossification of the common fibrous or cartilaginous bases of two bones proceeds from one point or centre, and so converts such bases into one bone: this is the case, *e.g.*, in the radius and ulna of the frog, and in its tibia and fibula. In both instances they are to the eye a single bone; but the mind, transcending the senses, recognises such single bone as being essentially two. In like manner it recognises the "occipital bone" of man as essentially four bones; but these have become "confluent," and were not "connate." The centrums of the two middle segments of the fish's skull are connate, and the little violence above recommended is requisite to detach the penultimate segment of the skull. When detached, the bones of it are seen to be so arranged as to form a neural and a hæmal arch. In the neural arch the centrum, neurapophyses, diapophyses, and neural spine are distinct: moreover, the neural spine in the cod, and many other fishes, is bifid, or split at the median line.* The centrum is called "basisphenoid," No. 5; the neurapophysis, "alisphenoid," No. 6; the neural spine, "parietal," No. 7; and the diapophysis, "mastoid," No. 8. The alisphenoids protect the sides of the optic lobes, and the rest of the penultimate segment of the brain; the mastoids project outwards and backwards as strong transverse processes, and give attachment to the piers of the great inverted hæmal arch. Before noticing the structure of this, I may remark that, in the recent cod-fish, the case, partly gristly, partly bony, which contains the organ of hearing, is wedged in between the last and penultimate neural arches of the skull. The extent to which the ear-case is ossified varies in different fishes, but the bone is always developed in the outer wall of the case. In the cod-fish it is unusually large, and is called "petrosal," No. 16; it forms no part of the segmented neuroskeleton. In the organ which it contributes to inclose, there is a body as hard as shell, like half a split almond: it is the "otosteal," No. 16, or proper ear-bone.

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* "Archetype Vert. Skel.," p. 11, Fig. 2.

The hæmal-arch consists of a pleurapophysis and a hæmapophysis on each side, and a hæmal spine; but all these elements are subdivided, the pleurapophysis into two parts, the upper one called "epitympanic," 28, *a* (common to this and the next arch in advance); the lower one "stylohyal," No. 38. The hæmapophysis is a broader, slightly arched bone; the upper division is called "epihyal," No. 39; the lower division, "ceratohyal," No. 40. The hæmal spine is subdivided into four stumpy bones, called collectively "basihyal," No. 41; and which, in most fishes, support a bone directed forwards, entering the substance of the tongue, called "glossohyal," No. 42; and another bone directed backwards, called "urohyal," No. 43.

The ceratohyal part of the hæmapophysis supports, in the cod, seven long and slender bent bones, called "branchiostegal rays," 44. The number of these rays differs greatly in different fishes: the *protopterus* has but one ray, the blenny has two rays, the carp three rays,—a very common number is seven; but the *elops* has thirty branchiostegal rays. They are of great length in the angler-fish (*lophius*), in which they serve to support a membrane, developed to form a large receptacle on each side of the head of this singular fish; into these receptacles, the small fishes are transferred, which the angler attracts within reach of its mouth, by the movable rod, line, and bait attached to the top of its enormous head. In ordinary fishes, the branchiostegal rays support a membrane which helps to close the gill-slit, and by its movements contributes to the direction of the branchial currents. It is an appendage, or rudimental limb, answering to the pectoral fin diverging from the hæmal arch, in the adjoining occipital segment.

The penultimate segment of the skull above described is called the "parietal vertebra;" and the hæmal arch is called the "hyoidean arch," in reference to its supporting and subserving the movements of the tongue.

The next segment, or the second of the skull, counting backwards, can be detached from the foremost segment without dividing any bone. It is then seen to consist, like the third and fourth segments, of two arches and a common centre; but the constituent bones have been subject to more extreme modifications. The centrum, called "presphenoid," No. 9, is produced far forwards, slightly expanding; the neurapophyses, called "orbitosphenoids," No. 10, are small semioval plates, protecting the sides of the cerebrum; the neural spine, or key-bone of the arch, called "frontal," No. 11, is enormously expanded, but in the cod and most fishes is single; the diapophyses, called "post-frontals," No. 12, project outwards from the hinder angles of the frontal, and give attachment to the piers of the inverted hæmal arch. The first bone of this arch is common in fishes to it and to that of the last described vertebra, being the bone called "epitympanic," No. 28 (Fig. 9); this modification is called for by the necessity of consentaneous movements of the two inverted arches, in connection with the deglutition and course of the streams of water required for the branchial respiration. The hæmal arch of the present segment—enormously developed—is plainly divided primarily on each side into a pleurapophysis and hæmapophysis; for these elements are joined together by a movable articulation, whilst the bones into which they are subdivided are suturally interlocked together. The pleurapophysis is so subdivided into four pieces; the upper one, articulating with the post-frontal and mastoid—the diapophyses of the two middle segments of the skull—is called "epitympanic," No. 28, *a*; the hindmost of the two middle pieces is the "mesotympanic," No. 28, *b*; the foremost of the two middle pieces is the "pretympanic," No. 28, *c*; the lower piece is the hypotympanic, No. 28, *d*; this presents a joint-surface, convex in one way, concave in the other, called a "ginglymoid condyle," for the hæmapophysis, or lower division of the arch. In most air-breathing vertebrates—the serpent, Cut 16, *e. g.*—the pleurapophysis resumes its normal simplicity, and is a single bone, 28, which is called the "tympanic;" in the eel-tribe it is in two pieces. The greater subdivision, in more actively breathing fishes, of the tympanic pedicle, gives it additional elasticity, and by their overlapping, interlocking junction, greater resistance against fracture; and these qualities seem to have been required in consequence of the presence of a complex and largely-developed diverging appendage, which forms the framework of the principal flap or door, called "operculum," that opens and closes the branchial fissure on each side. The appendage in question consists of four bones; the one articulated to the tympanic pedicle is called "preopercular," No. 34; the other three are, counting downwards, the "opercular," No. 35; the "subopercular," No. 36; the "interopercular," No. 37. The hæmapophysis is subdivided into two, three, or more pieces, in different fishes, suturally interlocked together; the most common division is into two subequal parts, one presenting the concavo-convex joint to the pleurapophysis, and called "articular," No. 29; the other, bifurcated behind to receive the point of 29, and joining its fellow at the opposite end, to complete the hæmal arch: it is very singularly modified by supporting, and having more or less firmly attached to it, a number of the hard bodies, called "teeth," and hence it has been termed the "dentary," No. 33. In the cod there is a small separate bone, below the joint of the articular, forming an angle there, and called the "angular piece," No. 31.

In consequence of this extreme modification, in relation to the offices of seizing and acting upon the food, the pair of hæmapophyses of the present segment of the skull have received the name of "lower jaw," or "mandible" (*mandibula*). The entire segment is called the "frontal vertebra."

The first segment, forming the anterior extremity, of the neuroskeleton, like most peripheral parts, is that which has undergone the most extreme modifications. The obvious arrangement, nevertheless, of its constituent bones, when viewed from behind, after its detachment from the second segment, affords one of the most conclusive proofs of the principle of adherence to common type which governs all the segments of the neuroskeleton, whatever offices they may be modified to fulfil. The neural arch plainly exists, but is now reduced to its essential elements—viz., the centrum, the neurapophyses, and the neural spine. The centrum is expanded anteriorly, where it usually supports some teeth on its under surface in fishes; it is called the "vomer," No. 13. The neurapophyses are notched (in the cod), or perforated (in the sword-fish), by the crura or prolongations of the brain, which expand into its anterior divisions, called "olfactory lobes;" the special name of such neurapophysis is "prefrontal," No. 14. The neural spine is usually single, sometimes cleft along the middle; it is the "nasal," No. 15.

The hæmal arch is drawn forwards, so that its apex, as well as its piers, are joined to the centrum (vomer) and usually also to the neural spine (nasal), closing up anteriorly the neural canal. The pleurapophyses are simple, short, sending backwards an expanded plate: they are called "palatines," No. 20. The hæmapophyses are simple, and their essential part, intervening between the pleurapophysis and hæmal spine, is short and thick; but they send a long process backwards. This element is called "maxillary," No. 21. The hæmal spine, cleft at the middle line, sends one process upwards of varying length in different fishes, and a second downwards and backwards; and its under surface is beset with teeth in most fishes: it is called "premaxillary," No. 22. Each pleurapophysis supports a "diverging appendage," consisting commonly of two bones: the outer one, which fixes the present hæmal arch to the succeeding one, is called "pterygoid," No. 24; the inner one is the "entopterygoid," No. 23. The entire segment is called the "nasal vertebra." The hæmal arch and its appendage form what is termed the upper jaw (*maxilla*); the palatine and pterygoids forming the roof of the mouth, the maxillary and premaxillary the proper upper jaw. On reviewing the arrangement of the bones of the foregoing segments, one cannot but be struck by the strength of the arches which protect and encompass the brain, and by the beauty and efficiency of that arrangement which provides such an arch for each primary division of the brain; and a sentiment of admiration naturally arises on examining the firm interlocking of the extended sutural surfaces, and especially of those uniting the proper elements of the arch with the buttresses wedged in between the piers and keystone, and to which buttresses (diapophyses) the larger hæmal arches are suspended.

In addition to the parts of the neuroskeleton, the bones of the head include the ossified part of the ear-capsule, "petrosal," 16, already mentioned; an ossified part of the eye-capsule, commonly in two pieces, "sclerotals," No. 17; and an ossified part of the capsule of the organ of smell, "turbinal," No. 19. Another assemblage of splanchnoskeletal bones support the gills, and are in the form of slender bony hoops, called "branchial arches." They are articulated to and supported by the hyoidean arch. Amongst the bones of the muco-dermal system, may be noticed those that circumscribe the lower part of the orbit, of which the anterior is pretty constant in the vertebrate series, and is called "lacrymal," marked 20 in Cut 9. In fishes they are called "suborbitals," and are occasionally present in great numbers, as, *e. g.*, in the tunny. A similar series of bones sometimes overarches the temporal fossæ, and are called "supertemporals."

At the outset of the study of Osteology it is essential to know well the numerous bones in the head of a fish, and to fix in the memory their arrangement and names. The latter, as we have seen, are of two kinds, as regards the bones of the neuroskeleton; the one kind is "general," indicative of the relation of the skull-bones to the typical segment, and which names they bear in common with the same elements in the segments of the trunk; the other kind is "special," and bestowed on account of the particular development and shape of such elements, as they are modified in the head for particular functions. I would advise any one earnestly desirous of comprehending this beautiful department of Comparative Anatomy to obtain a prepared and partially disarticulated skull of a cod-fish from Mr. Flower,* in which every bone bears the initials of its "general" name, and the numerals indicative of its "special" name. A great proportion of the bones in the head of a fish exist in a very similar state of connection and arrangement in the heads of other vertebrata, up to and including man himself. No method could be less conducive to a true and philosophical comprehension of the vertebrate skeleton than the beginning its study in man—the most modified of all vertebrate forms, and that which recedes furthest from the common pattern. Through an inevitable ignorance of that pattern, the bones in anthropotomy are indicated only by special names more or less relating to the particular forms these bones happen to bear in man; such names, when applied to the tallying bones in lower animals, losing that significance, and becoming arbitrary signs. Owing to the frequent modification by confluence of the human bones, collections of them, so united, have received a single name, as, *e. g.*, "occipital," "temporal," &c.; whilst their constituents, which are usually distinct vertebral elements, have received no names, or are defined as processes, *e. g.*, "condyloid process of the occipital bone," "styloid process of the temporal bone," "petrous portion of the temporal bone," &c. The classification, moreover, of the bones of the head in Human Anatomy, viz., into those of the cranium and those of the face, is artificial or special, and consequently defective. Many bones which essentially belong to the skull are wholly omitted in such classification.

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* *Ante*, p. 173.

In regard to the archetype of the vertebrate skeleton, fishes, which were the first forms of vertebrate life introduced into this planet, deviate the least therefrom; and according to the foregoing analysis of the bones of the head, it follows that such bones are primarily divisible into those of—

The Neuroskeleton;
The Splanchnoskeleton;
The Dermoskeleton.

The neuroskeletal bones are arranged in four segments, called—

The Occipital segment;
The Parietal segment;
The Frontal segment;
The Nasal segment.

Each segment consists of a "neural" and a "hæmal" arch. The neural arches are—

N I. Epencephalic arch (bones Nos. 1, 2, 3, 4);
N II. Mesencephalic arch (5, 6, 7, 8);
N III. Prosencephalic arch (9, 10, 11, 12);
N IV. Rhinencephalic arch (13, 14, 15).

The hæmal arches are—

H I. Scapular arch (50-52);
H II. Hyoidean arch (38-43);
H III. Mandibular arch (28-32);
H IV. Maxillary arch (20-22).

The diverging appendages of the hæmal arches are—

1. The Pectoral (54-57);
2. The Branchiostegal (44);
3. The Opercular (34-37);
4. The Pterygoid (23-24).

The bones or parts of the splanchno-skeleton which are intercalated with or attached to the arches of the true vertebral segments, are—

The Petrosal (16) or ear-capsule, with the otolites, 16″;
The Sclerotal (17) or eye-capsule;
The Turbinal (19) or nose-capsule;
The Branchial arches;
The Teeth.

The bones of the dermoskeleton are—

The Supratemporals;
The Superorbitals;
The Suborbitals;
The Labials.

Such appears to be the natural classification of the parts which constitute the complex skull of osseous fishes.

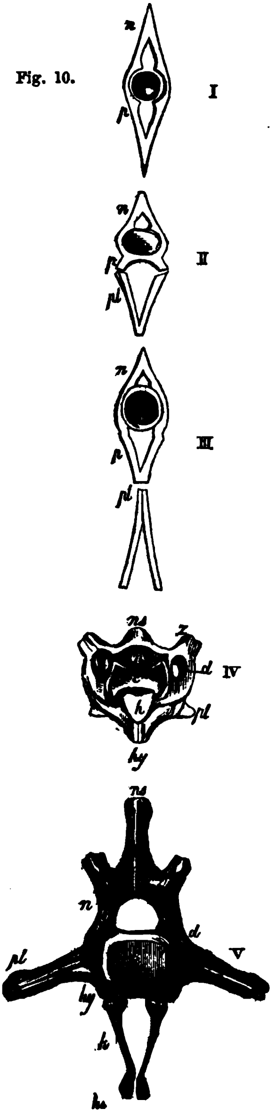
The term "cranium" might well be applied to the four neural arches collectively, but would exclude some bones called "cranial," and include some called "facial," in Human Anatomy. In a side view of the naturally-connected bones of the head of a fish, such as is shown in the figure of the skeleton of the sea-perch, Cut 9, the upper part of the head is formed by the neural spines called superoccipital, 3, frontal, 11, and nasal, 15: produced at the hinder half into the median ridge. The right lateral ridge is formed by the parietal, 7, and paroccipital, 4; the external ridge by the post-frontal, 12, and the mastoid, 8. The anterior termination of the series of centrums may be partly seen through the widely-open orbits at 9 and 13, indicating the pre-sphenoid and vomer respectively. The most conspicuous parts of the upper jaw are the premaxillary, 22, and the maxillary, 21, the latter being edentulous, as in most fishes: the salmon and trout are examples where No. 21 bears teeth. The shape and slight attachment of those bones relate to the necessity of a movable mouth that can be protruded and retracted, in a class of animals that derive no aid in the prehension of their food from their limbs, which are reduced to fins. The upper bent back part of the premaxillary is called its "nasal branch," and is of unusual length in fishes with protractile snouts, as, *e. g.*, the dories (*Zeus*), certain wrasses (*Coricus*), and especially the sly-bream (*Sparus insidiator* of Pallas). In this fish the nasal branch of the premaxillary plays in a groove on the upper surface of the skull, and reaches as far back as the occiput, when the mouth is shut and retracted. The descending branch of the premaxillary is attached by a ligament to the maxillary, and, as this is similarly attached to the mandible, both are protruded, when the long nasal branch of the premaxillary is drawn forwards out of its epicranial groove. This action is aided by the hypotympanic, which is of great length, and has a movable articulation at both ends; the lower end joining the mandible is pulled forward, simultaneously with the protrusion of the premaxillary, and co-operates therewith in the sudden projection of the mouth, by which the sly-beam seizes, or shoots with a suddenly-propelled drop of water, the small agile aquatic insects that constitute its prey.

An opposite extreme of modification of the maxillary and premaxillary bones, where unusual fixity and strength are needed, is that presented by the "sword-fishes," in which the premaxillaries constitute, by an unusual prolongation and density of tissue, the sword-shaped weapon characteristic of the genera *Xiphias* and *Istiophorus*.

In Cut 9 the divisions 28 *a*, *c*, and *d*, of the tympanic pedicle, and the two chief divisions, 29 and 33, of the mandible, are shown, together with the four bones of the opercular appendage; the preopercular, 34, being serrated and spined, as in most perches.

Of the hyoidean arch may be seen the glossohyal, 42, the ceratohyal, 40, with its branchiostegal rays, 44, and the urohyal, 43. Of the scapular arch, the scapula, 51, and the coracoid, 52, this supports not only the bones of the "pectoral fin," P, viz., ulna, radius, with the small carpal bones intervening between them and the metacarpophalanges, 57, but also the lower elements of the pelvic arch, 63, and their diverging appendage, 69, called the "ventral fin," V.

Fig. 10.



In the segments of the trunk the hæmapophyses, save in the first vertebra, 58, and the pelvic vertebra, 63, are not ossified; but they are represented by aponeurotic fascia continued downwards from the ossified elements of the segments; these elements consist of the centrum, the neurapophyses, and neural spines, the pleurapophyses, and the parapophyses. In most fishes the neural spines are connate with the neurapophyses, and these become confluent with the centrums in most of the segments: the neurapophyses are perforated directly by the spinal nerves in many fishes, as at *n n* (Fig. 8); they usually develop anterior zygapophyses, Z (Fig. 9). The centrums are biconcave in all fishes, save the lepidosteus, in which they are convex in front, and concave behind. The pleurapophyses, *pl* (Fig. 9), form what are called "false ribs," or free or "floating ribs," in Anthropotomy: they articulate with the centrums in the anterior trunk-vertebræ, and then with the parapophyses, *p*, which are usually confluent with the centrum. The parapophyses elongate, bend down, and unite together at or near to the end of the abdomen, and so form the contracted hæmal canal, for the caudal vessels, in the long and muscular tail of the fish. The trunk-vertebræ of a fish are divisible into those which have free pleurapophyses, called "abdominal vertebræ," and those without, and which terminate below by narrow hæmal arches and long spines, called "caudal vertebræ." These hæmal arches are formed by different parts in different fishes: commonly by the bent-down and terminally confluent parapophyses (Fig. 10), I, *p*, cod; sometimes, as in the tunny (*ib.*) III, by parapophyses, *p*, lengthened out by pleurapophyses, *pl*; sometimes, as in lepidosteus (*ib.*), II, by pleurapophypses, *pl*; but never, as in air-breathing vertebrates (*ib.*), V, by ossified hæmapophyses, *h*, *hs*. These elements, in the first vertebra of the trunk of a fish, are, indeed, ossified, and form the long and slender bone called "clavicle," 58 (Fig. 9), usually attached to the inner side of the scapular arch. The hæmapophyses of, probably, the last abdominal vertebra, called "ischia," No. 63, are detached from the rest of their segment, and are either loosely suspended in the flesh, beneath or near it, as in the fishes called "abdominal;" or they are advanced, much elongated, and attached to the scapular arch, as in the fishes called "thoracic" (Fig. 9); or they are more advanced, shortened, and similarly attached, as in the fishes called "jugular;" or they are wholly wanting, as in the fishes called "apodal." The fins called "ventral," V, supported by the pelvic hæmapophyses, indicate by their position the orders of fishes called "abdominal," "thoracic," and "jugular," by Linnæus.

The only proper fins in pairs are the "pectoral," P, answering to the fore-limbs of quadrupeds, and the "ventral," V, answering to the hind-limbs. The rest of the fins are single and median in position, and are due to folds of the skin, in which certain dermal bones are developed for their support. These bones are of two kinds: one, dagger-shaped, are plunged, so to speak, up to the hilt, in the flesh between the neural spines, and between the hæmal spines; those along the upper surface of the fish are called "interneural spines," *in*, Cut 9; those on the under surface are the "interhæmal spines," *ih*. The interneural spines support the "dermoneural spines, *dn*, forming the rays of the dorsal fin or fins, D1, D2, and the upper rays of the caudal fin. The interhæmal spines support the dermohæmal spines, *dh*, which form the rays of the anal fin, A, and the lower rays of the caudal fin, *dh*, C.

Both dermoneural and dermohæmal spines may present two structures; they may be simple, unjointed, firm, bony spines; or they may be flexible, jointed, and branched rays. Those fishes which have one or more of the hard spines at the beginning of the pectoral, ventral, dorsal, and anal fins are called "acanthopterygian," or spiny-finned fishes (Gr. *acanthos*, spine; *pterux*, fin); those in which the vertical fins are supported by soft spines are called "malacopterygian," or soft-finned fishes (Gr. *malakos*, soft; and *pterux*). Ichthyologists avail themselves of the number and kind of rays in the fins to characterize the species of fishes, and adopt an abbreviated formula and symbols to express these characters.

In regard to the sea-perch (Fig. 9), the fin-formula would be as follows:—

$$D\ 7,\ 1 + 12 : P\ 12 : V\ 1 + 5 : A\ 3 + 8 : C\ 18,$$

which signifies that D, the dorsal fin, has, in its first division, 7 rays, all spinous: in its second division, 1 spinous + (plus) 12 rays that are soft. P, the pectoral fin, has 12 rays, all soft. V, the ventral fin, has 1 spinous + 5 soft rays. A, the anal fin, has 3 spinous + 8 soft rays. C, the caudal fin, has 18 rays.

When the piscine modification of the vertebrate skeleton is contemplated in relation to the life and movements of a fish in its native element, every departure from the archetype is seen to be in direct relation to the habits and well-being of the species.

The large head has been compared to the embryonic disproportion of that part in higher vertebrates; but the head of a fish should be of the size and shape best fitted to overcome the resistance of water, and to facilitate rapid progression through that element: the head must, therefore, grow with the growth of the body. Accordingly, the large skull-bones always show the radiating bony filaments in their clear circumference, which is the seat of growth; and hence the number of overlapping squamous sutures which least oppose the progressive extension of the bones. The cranial cavity expands with the expansion of the skull, but the brain undergoes no corresponding increase; it lies at the bottom of its capacious chamber, which is principally occupied by a loose cellular tissue, situated, like the "arachnoid" membrane in man, between the brain-tunics, called "pia mater" and "dura mater," and having its cells filled by a light, oily fluid; thus the head is rendered specifically lighter than if growth only, and not the modelling absorption also, had gone on. The loose connection of the hæmal arches and their parts, including most of what are called "bones of the face," seems like the retention of a condition observable in the partially-developed skull of the embryos of higher animals; but this condition is subservient to the peculiar and extensive movements of the jaws, and of the bony supports of the breathing machinery. Not any of the limbs of fishes are prehensile; the mouth may be propelled by them to the food, but the act of taking it must be performed by the jaws; these can, accordingly, be not only opened and shut, but can be protruded and retracted. The division of the long tympanic pedicle into several partly-overlapping pieces adds to its strength, and by a slight elastic yielding diminishes the liability to fracture. The tongue, to judge by its structure, seems to serve little as an organ of taste, but the arch sustaining it has much to effect in the way of swallowing. for this action relates not merely to food; the mechanical part of breathing is a modified, habitual, and frequent act of deglutition. The hyoid arch is the chief support of the branchial arches and gills; and the branchiostegal membranes, stretched out upon the diverging rays of the hyoid arch, regulate the course and exit of the respiratory currents.

By the retraction of the hyoid arch the opercular doors are forced open, and the branchial cavity is widened, whilst all entry from behind is prevented by the branchiostegal flaps, which close the external gill-openings, The water, therefore, enters by the gaping mouth, and rushes through the sieve-like interspaces of the branchial arches into the branchial cavity; the mouth then shuts, the opercular doors close upon the branchial and hyoid arches, which again swing forwards; and the branchiostegal membranes being withdrawn, the currents rush out at the gill-openings. Thus the mechanical functions of the hæmal arches of the thorax of the higher air-breathing classes are transferred to the hæmal arches and appendages of the skull in fishes.

The persistent gills and gill-arches in fishes have been compared with the same parts which are transitory in frogs, and with some traces of branchial organization in the embryos of higher vertebrates: and fishes have been called, in the language of the transmutation-of-species hypothesis, "arrested gigantic tadpoles." It will be found, however, that so far from there having been any stoppage of development, the branchial arches have been adapted to the exigencies of the fish by advancing to a grade of structure which they never reach in the frog. This is shown by their firm ossification, and their numerous elastic joints; the sieve-like valves developed from the side next the mouth have been pre-arranged, with the utmost complexity and nicety of adjustment, to prevent the entry of any particles of food, or other irritating matters, into the interspaces of the tender, vascular, and sensitive gills. It is interesting, also, further to observe, that the last pair of these arches, which, when the embryo-fish is as yet edentulous, usually support gills, are reduced, when the supply of yolk-food is exhausted, and the jaws get their prehensile organs, to the capacity of the gullet, become thickened, in order to support teeth for tearing in pieces, mincing, or crushing the food, and are converted into an accessory pair of jaws, and this pair the most important of the two, as it would seem; for the carp-tribe—*e. g.*, tench, barbel, roach—which have no teeth on their proper jaws, have teeth on the pharyngeal jaws. In no other vertebrate animals, save the osseous fishes, is the mouth provided with maxillary instruments at both the fore and hind apertures; and in no other part of the piscine structure is the direct divergence from any conceivable progressive scale of ascending organisms, culminating in man, so plainly marked as in this.

The general form of the fish is admirably adapted to the element in which it lives and moves. The viscera are packed in a moderate compass, in a cavity brought forwards close to the head. The absence of any neck gives the advantage of a more extensive and resisting attachment of the head to the trunk, and a greater proportion of the trunk is left free for the allocation of the muscular masses which move the tail. In the "caudal" division of the vertebral column, the parapophyses cease to extend outwards; they bend downwards, unite and elongate in that direction, proportionally with the elongation of the spines above, whilst dermal and intercalated spines shoot forth from the middle line above and below, giving the vertically extended, compressed form to the hinder half of the body, by the alternating lateral strokes of which the fish is propelled forwards in the diagonal between the direction of those forces. The advantage of the biconcave form of vertebra, with intervening elastic capsules of gelatinous fluid, in producing a combination of the resilient with the muscular power, is as obvious as it is beautiful to contemplate.

The fixation and coalescence of any of the vertebra in this locomotive part of the fishes' body, analogous to the part called "sacrum" and "pelvis" in land quadrupeds, would be a great hindrance to the alternate and vigorous inflections of that part, by which mainly the fish swims. A "sacrum" is a consolidation of part of the vertebral axis of the body, for the transference of more or less of the weight of that body upon limbs organized for its support on dry land; such a modification would have been not merely useless, but a hindrance to a fish. The pectoral fins are the prototypes of the fore-limbs of the higher vertebrates. With their terminal segment, or "hand," alone projecting freely from the trunk, and swathed in a common sheath of skin, they present an interesting analogy to the embryonal buds of the answerable members in man. But what would have been the result if both arm and fore-arm had extended freely from the side of the fish, and dangled as a long many-jointed appendage in the water! This "higher development," as it is termed, in relation to the prehensile or cursorial limb of the denizen of dry land, would have been a defect in the structure of a creature destined to cleave the liquid element. In the fish, therefore, the fore-limb is left as short as was compatible with its required functions: the broad, many-fingered hand alone projects, but can be applied prone and flat, by flexion of the wrist, to the side of the trunk; or it may be extended with its flat surfaces turned forwards and backwards, so as to check and arrest, more or less suddenly, the progress of the fish; its breadth can also be diminished by closing up or stretching out the digital rays. In the act of flexion, the pectoral fin slightly rotates, and gives an oblique stroke to the water. The requisite breadth of the modified hand is gained by the addition of ten, twenty, or it may be a hundred fingers over and above the number to which they are restricted in the fore foot or hand of the higher classes of vertebrata. The pike maintains a stationary position in a stream by vibrations of the pectoral fins: the nature of the bottom of the fish's habitat is ascertained by a tactile application of the same fins. In the hard-faced gurnards certain rays of the pectorals are liberated from the web, and have a special endowment of nerves, in order to act as feelers. In the siluroid fishes, the pectorals wield a formidable weapon of offence. A tropical species of perch (*Anabas*) uses a smaller analogous pectoral spine for climbing up the mangrove stems in quest of insects.

Certain lophioid fishes that live on sand banks left dry at low water, are enabled to hop after the retreating tide by a special prolongation of the carpal joint of the pectoral fin, which projects in these "frog fishes," as they have been termed, like the limb of a land quadruped, and presents two distinct segments clear of the trunk.

The sharks, whose form of body and strength of tail enable them to swim near the surface of the ocean, are further adapted for this sphere of activity, and compensated for the absence of an air-bladder, by the large proportional size of their pectoral fins, which take a greater share in their active and varied evolutions than in ordinary fishes; more especially in producing that half turn or roll of the body required to bring the mouth, which is on the under part of the head, in contact with their prey. The maximum of development of the many-fingered hands is attained in the rays, and in those fishes—*e.g.*, *Exocœtus* and *Dactylopterus*—called "flying fishes," in consequence of the pectorals being long enough, and their webs broad enough to sustain them in the air, in their long "flying leaps" out of the water.

With regard to the ventral fins—the rudiments of hind-limbs—these combine merely with the pectorals in raising the fish, and in preventing, as outriggers, the rolling of the body during progression. In the long-bodied and small-headed abdominal fishes the ventrals are situated near the vent, where they best subserve the office of accessory balancers; in the large-headed thoracic and jugular fishes they are transferred forwards, to aid the pectorals in supporting and raising the head. If the pectoral and ventral fins in one of these fishes be cut off, the head sinks to the bottom; if the right pectoral fin only be cut off, the fish leans to that side; if the ventral fin on the same side be cut away, then it loses its equilibrium entirely; if the dorsal and anal fins be cut off, the fish reels to the right and left; when the caudal fin is cut off, the fish loses the power of progressive motion; when the fish dies, and the fins cease to play, the belly turns upwards.

Paley thus sums up the actions of the fins of fishes:—"The pectoral, and more particularly the ventral, fins serve to raise and depress the fish; when the fish desires to have a retrograde motion, a stroke forward with the pectoral fin effectually produces it; if the fish desire to turn either way, a single blow with the tail the opposite way sends it round at once; if the tail strike both ways, the motion produced by the double lash is progressive, and enables the fish to dart forwards with an astonishing velocity. The result is not only in some cases the most rapid, but in all cases the most gentle, pliant, easy animal motion with which we are acquainted." "In their mechanical use, the anal fin may be reckoned the keel; the ventral fins, the outriggers; the pectoral fins, the oars;" and we may now add "the caudal fin, the screw-propeller." And if there be such similitude between those parts of a boat and a fish, "observe," adds Paley, "that it is not the resemblance of imitation, but the likeness which arises from applying similar mechanical means to the same purposes."*

Principal Forms of the Skeleton in the Class Reptilia.—The transition from fishes to reptiles is easy, and the signs thereof very manifest in the skeleton. In the thornback and allied fishes the skull articulates with the trunk by two condyles, and the part answering to the basioccipital is a depressed plate. The *Batrachia*, or lowest order of reptiles—including the siren, proteus, frog, toad—have a similar double articulation of the skull with the trunk, the two condyles being developed from the two exoccipitals. Hæmapophyses are not present as bones in the abdominal part of the trunk of *Batrachia*, but they are so developed in the tail. This structure, with the detachment of the scapular arch from the occiput, and the absence of dermoneural and dermohæmal spines, serves to distinguish the most fish-like batrachian from the protopterus and lepidosiren, which are the most reptile-like of fishes.

In commencing the study of the skeletons of reptiles in the most fish-like of the class, we find a much less complex condition of the osseous framework of the body than in the bony fishes; this will be immediately manifest by a comparison of the skeleton of the menopome (which may be seen in the Museum, Royal College of Surgeons, No. 583), as an example of the perennibranchiate batrachia, with the skeleton of the trout (No. 45) or of the haddock (No. 176, in the same Museum).

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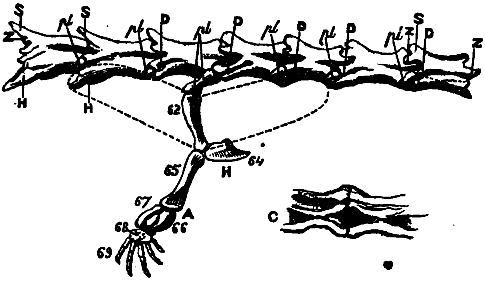
* "Nat. Theology," 8vo, 1805, p. 257.

The difference tends greatly to elucidate the true nature of the complexities of the fish's skeleton, since it chiefly consists in the simplification of that of the batrachian, by the non-development of the parts of the dermal skeleton which characterize that of the fish. The suborbital, superorbital, and supratemporal scale-bones are removed, together with the opercular bones, from the head; and the interneural and dermoneural spines, with the interhæmal and dermohæmal spines, are removed from the trunk. The endoskeleton is also reduced to a very simple condition; the advance characteristic of the higher class being appreciable only by a comparison of it with the skeleton of the most batrachoid of fishes—*e. g.*, the protopterus (No. 380).

We then perceive that the bodies of the vertebræ, in the true batrachian, are distinctly ossified, though preserving, in the perennibranchiate species, a deep, conical, jelly-filled cavity both before and behind (Cut 11), C; they have also coalesced with the neural arches, as these have with their spines, which are, however, scarcely prominent, except in the tail. The transverse processes are developed not only from the centrum but from the base of the neural arch, and are formed by both parapophyses and diapophyses; and they coexist with distinct hæmapophyses in the tail (*ib.*), H. With these, likewise, coexist cartilaginous pleurapophyses (*ib.*), *pl*, in the second, third, and fourth caudal vertebræ; short ossified pleurapophyses being developed from the ends of the diapophyses in the first caudal to the vertebra dentata inclusive.

Fig. 11.



SACRAL VERTEBRA AND CONTIGUOUS VERTEBRÆ—MENOPOME.

By this instructive condition of the skeleton of the menopome, we perceive at once that the hæmapophyses (*ib.*), H, are neither transverse processes, nor ribs bent down or displaced, but are elements of vertebræ, as distinct as the neurapophyses above. The neural arches are now articulated together by well-developed zygapophyses with synovial articulations, which are absent in the protopterus, as in most fishes.

In the protopterus, as in the squatina and some other cartilaginous fishes, the neural arch of the atlas rests upon a backward production of the basioccipital; in the batrachians it is confluent with its own proper centrum, which developes two articular surfaces for the two occipital condyles. The hæmal arch of the occipital segment, which is attached to its proper vertebra in the protopterus (Fig. 32), A, 51, 52, as in osseous fishes, is detached and displaced backwards in the batrachians (Fig. 33), 51, 52. In the completion of the hæmal arch of the sacral vertebra in the menopome, by the enlargement of its transverse process (Fig. 11), D, and by its pleurapophysis (*ib.*), *pl*, extended to join a hæmapophysis (*ib.*), H, below, we have the key to the essential nature of the pelvis in all air-breathing animals. The progressive development of the appendages of the scapular and pelvic arches, which are to become the four limbs of air-breathing vertebrates, should be traced from their condition in the protopterus. Here (Fig. 32) they are reduced to a single ray, which is soft and many-jointed. In the *Amphiuma* *didactyla* (Fig. 33) the ray is ossified: its first joint (*ib.*), 53, is long, its second (*ib.*), 54, 55, is bifid, and a cartilage at the end of this supports two short terminal rays. This is the pattern of the subdivision of the appendage both of the scapular and pelvic arches, in all the higher vertebrates: hence, in consequence of the vast modifications of the several segments, the necessity for their special names. In the fore-limb the first segment (Fig. 33), 53, is the "arm," and its bone, the "humerus," No 53; the second segment is the fore-arm—its two bones are the "radius," No. 55, and "ulna," No. 54; the third segment is the "hand"—its rays are the "fingers;" and its bones are subdivided into "carpals," No. 56, "metacarpals," and "phalanges," No. 57. In the hind-limb (Fig. 34) the *first* segment is the "thigh," and its bone, the "femur," No. 65; the second segment is the "leg," and its two bones are the "tibia" No. 66, and "fibula," No. 67; the third segment is the "foot"—its rays are the "toes;" its bones are subdivided into "tarsals," "metatarsals," and "phalanges."

In the siren the pelvic arch and limbs are not developed; but they coexist with the scapular arch and limbs in all other batrachia. In the proteus the last segment of the fore-limb divides into three rays, that of the hind-limb into two rays; in other words, it has three fingers and two toes. The menobranchus has four fingers and four toes. The axolotl has four fingers and five toes. The menopome has five fingers and five toes.

The ultimate subdivisions of the radiated or diverging appendages of the scapular and pelvic arches do not exceed five in any existing air-breathing animal, and their further complexity is due to the specialization of each digit, so as to combine in associated action, instead of their indefinite multiplication, which causes the seeming complexity of the same appendages in fishes.

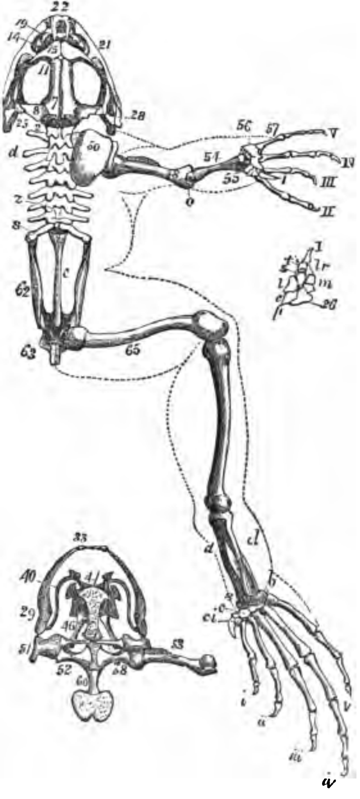
In all the fish-like batrachia, called, from a retention of more or less of the branchial apparatus, "perennibranchia," the limbs are short, and the rays of the terminal segments of each limb are, more or less, united by a web: the body is long, and the tail long and compressed. But a great ascent in the scale of life is made in the batrachian order: all the species when hatched have the fish-like form, and gills for breathing water; most of them exist for some time, under this form, in water; and these undergo so strange a modification of form and structure before arriving at maturity, that it has been called a "metamorphosis." They change their aquatic for a terrestrial life; they breathe air instead of water; and from being omnivorous become carnivorous. The tadpoles of our common toad and frog afford ready and abundant instances for tracing these stages. The following is an outline of the main phenomena of the change observable in regard to the osseous system:—

In the development of the skeleton of the common frog, a fibrous and cartilaginous framework is originally laid down conformably with the aquatic habits and life of the larva. A large cartilaginous cranium with four hæmal arches, and one of these supporting the framework of the branchial apparatus,—a short series of fibro-cartilaginous vertebræ, minus the hæmal arches, in the trunk, and a series of fibrous septa diverging from the fibrous capsule of the notochord, and defining and giving attachment to the muscular segments along the tail,—constitute the skeleton of the newly hatched tadpole. As it grows, ossification begins; but only in those part of the skeleton which are to be retained in the future frog. Thus, the centrums and neurapophyses of the head and trunk are ossified, but not those of the tail. In the trunk, ossification of the vertebral body proceeds centripetally by layers, successively diminishing in extent, and conical interspaces are left, consisting of the changed fibrous capsule of the notochord with the inclosed gelatinous cells, their liquefied contents forming the balls of fluid, between the biconcave vertebræ, as in fishes. But ossification proceeds to fill up the hinder cavity of the centrum, and to project into the front cavity of the succeeding vertebra, with which it is finally connected by a synovial ball-and-socket joint. Thus, the firmer intervertebral articulations are established, which adapt the vertebral column to the support of a body which is to be suspended upon limbs, and transported by them along the surface of the dry ground. Whilst this change is proceeding, the tail is undergoing rapid absorption, the retained fibro-cartilaginous condition of its vertebræ rendering them more ready for removal. In the last fused rudiments of the caudal vertebræ, ossification extends continuously, and the peculiar style (Fig. 12), *c*, at the end of the vertebral series in the frog and other tail-less batrachians, is thus established.

In the conversion of the biconcave into cup-and-ball vertebræ in batrachian larvæ, ossification commonly, but not always, proceeds to obliterate the hinder cavity. In the land salamanders, however, it extends from the front cavity; so that in the adult vertebræ the ball is anterior, and the cup posterior, as in certain salamandroid fishes—*e. g.*, *lepidosteus*. In those batrachians that retain more or less of the branchial apparatus, with the outward form and natatory tail adapted to aquatic life, the vertebræ of the tail are ossified like those of the trunk, but the biconcave structure and intervening gelatinous joints are retained throughout life.

The chief changes which take place in the conversion of the cartilaginous skull of the larva to the ossified one of the imago, or perfect frog, are seen in the shape and relative position of the hæmal arches and their appendages—*i. e.*, of the maxillary, mandibular, hyoid, and scapular arches. The maxillary arch expands in breadth, the mouth widens, and the horny mandibles are shed. As the mouth advances forwards, the tympanic pedicles are elongated, and are placed more obliquely; their proximal end retrograding from the post-frontal to the mastoid region of the skull, and their distal end inclining forwards with the attached lower jaw, Nos. 29, 33, on which the denticles now begin to be developed. For the still more extraordinary changes of the hyoid arch, No. 41, and its branchial appendages, No. 46, the student is referred to Dugè's "Recherches sur l'Ostéologie des Batraciens," 4to, 1835; and to the writer's "Archetype of the Vertebrate Skeleton," pp. 70, 71.

Fig. 12.



SKELETON OF THE FROG (*Rana esculenta*).

The scapular arch, which was close to the occiput, whilst protecting and supporting the branchial heart—its primary function—begins, as the rudiments of the fore-limbs bud out, to recede backwards, like the mandibular and branchial arches, but to a greater extent, the attachment to the occipital segment being wholly lost. The scapular and coracoid portions of the arch become first ossified; the suprascapular plate remains long cartilaginous, and always partly so; the sternum is developed in proportion as the hyoid arch is reduced, and the branchial arches are removed; thus a strong fulcrum is completed for the articulation of the shoulder-joints. The pelvic arch had previously been completed, and the iliac bones and sides of the sacrum become co-elongated: then the ilia continue to extend backwards as the tail is being absorbed, and the hind-limbs are lengthened out and finished.

Thus metamorphosed, the skeleton of the frog presents the following structure (Fig. 12):—The number of vertebræ of the trunk, exclusive of the coxygeal style, *c*, is nine; the first, or atlas, has no diapophyses, but these are present and long on the rest, especially on the third, *d*, and ninth, *s*, vertebræ; in the latter they are thick, stand outwards, and support two other long, curved, rib-like bones, 62, which expand at their distal ends, and unite to two bony plates, 63, completing the hæmal arch of the ninth segment of the trunk. The bones of the hinder extremities are attached to the point of union of the above costal and hæmal pieces, one of which answers to the ilium, 62, and the other to the ischium, 63. The superior development of this arch relates to the great size and strength of the hinder extremities in the tail-less tribe. The bodies of the vertebræ are articulated by ball-and-socket joints, the cup being anterior, the ball posterior, a modification which relates to the more terrestrial habits and locomotion of these higher-organized batrachia. The caudal vertebræ are represented by a single, elongated, cylindrical style, *c*, having an anchylosed neural canal. In the seven vertebræ, between the atlas and the sacrum, two zygapopophyses, looking upwards, two zygapophyses, *z*, looking downwards, and a short spine, are developed from each neural arch.

The suprascapula, 50, is very broad, and in great part ossified; the scapula, 51, divides at its humeral end into an acromial and coracoid process; the latter articulates with the true coracoid bone, 52, the acromion with the expanded extremity of the clavicle, 58: the glenoid cavity is formed by both the scapula and the coracoid. An episternal bone, 59, supporting a broad cartilage, is articulated to the mesial union of the clavicles, from which a bony bar is continued backwards between the expanded and partially conjoined ends of the coracoids. The sternum, 60, is articulated to the posterior part of the same extremities of the coracoids, and supports a broad "xiphoid" cartilage.

The proximal end of the humerus, 53, is an epiphysis; the distal end presents a hemispherical ball between a small external ridge, and a large internal condyloid process. The antibrachial bones have coalesced, but an anterior and posterior indentation at the distal half indicates the radius, 55, ahd ulna, 54; their distal articular extremities are represented by a single epiphysis. The ulnar portion of the bone developes a short and broad olecranon, *o*. The bones of the carpal series now receive definite names, and are as follows:—(Fig. 12), *s*, scaphoid; *l*, lunare; *c* and *p*, cuneo-pisiforme; *t*, trapezium; *tr*, trapezoides; *m*, magnum; *u*, unciforme—here two distinct bones. The first digit, I, has one bone, a metacarpal; the second digit, II, has a metacarpal and two phalanges; the third, III, the same; the fourth, IV, has a metacarpal and three phalanges; and the fifth, V, the same.

Both the proximal and the distal extremities of the femur, 65, are in the condition of epiphyses. The tibia and fibula are connate, 66: a longitudinal impression on the front and back part of the expanded distal end indicates their division, but a single epiphysis, partially anchylosed, forms the proximal extremity, and a similar one the distal extremity, of the connate bones; they are perforated near their middle, from before backwards, by a vascular canal. The tarsal bones are now distinguished by names.

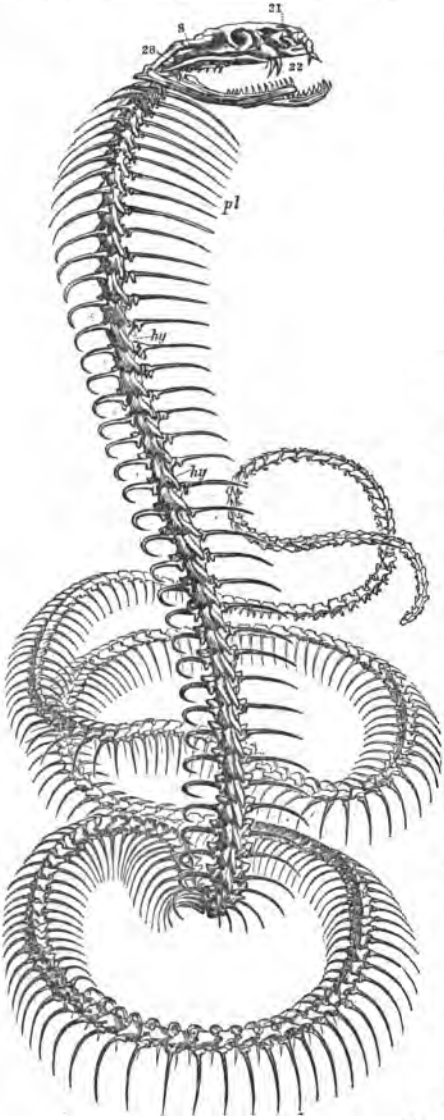


Fig. 13.—SKELETON OF THE COBRA (*Naŷá tripudians*).

The astragalus, *a*, and calcaneum, *cl*, are much elongated; the former is slightly bent, the latter straight; they have coalesced at their proximal and also at their distal extremities with each other, and with the scaphoid, *s*, and cuboid, *b*, bones. Three cuneiform bones, *c*, *ci*, remain detached, and immediately support the three inner toes and a cartilaginous appendage. The first toe, *i*, and second toe, *ii*, have each a metatarsal and two phalanges; the third toe, *iii*, has a metatarsal and three phalanges; the fourth toe, *iv*, has a metatarsal and four phalanges; the fifth toe, *v*, a metatarsal and three phalanges. The great length and strength of the pelvic arch, and its appendages, the hind-limbs, give the frog the power of executing the long leaps for which it is proverbial.

All the batrachia present this structure in common with fishes, viz., that the ribs of the trunk, when present, are free, consist only of "pleurapophyses," and do not encompass the thoracic-abdominal cavity. The absence of unyielding osseous girdles at this part seems to relate to a peculiarity of their generation, viz., the almost simultaneous ripening of the sperm-cells and ova, causing a great and sudden distension of the abdomen at the breeding period.

Osteology of the Ophidia, or Serpent Tribe.—There are certain tropical land batrachia—the Ceciliæ, *e. g.*—in which the body is as long and slender as in serpents, includes almost as numerous vertebræ, and is devoid of all trace of limbs. But the osteology of the typical Ophidian reptiles differs from that of the batrachians in the more elongated ribs; in the distinct basi- and superoccipitals; in the superoccipital forming part of the ear-chamber; in the basioccipital combining with the exoccipital to form a single articular condyle for the atlas; in the ossification of the membranous space between the elongated parietals and the sphenoid; in the constant coalescence of the parietals with one another; in the constant confluence of the orbitosphenoids with the frontals, and in the meeting of the orbitosphenoids below the prosencephalon, upon the upper surface of the presphenoid; in the presence of distinct postfrontals, and the attachment thereto of the ectopterygoids, whereby they form an anterior point of suspension of the lower jaw, through the medium of the pterygoid and tympanic bones; lastly, in the connation of the prefrontals and lacrymals.

In studying the osteology of the head of the python, as the type of the Ophidian Order, by the aid of the following description, the student may compare the disarticulated skull, No. 628, with that of the large skeleton, No. 602, in the Museum, Royal College of Surgeons: the bones are numbered as here referred to.

The basioccipital, 1, is subdepressed, broadest anteriorly, subhexagonal; smooth and concave at the middle above, with a rough sutural tract on each side, and a hypapophysis below, produced into a recurved point. The hinder facet of the basioccipital is convex, forming the lower half of the occipital condyle, which is supported on a short peduncular prolongation. The basioccipital unites above and laterally with the exoccipitals and alisphenoids, and in front with the basisphenoid, upon which it rests obliquely, and it supports the medulla oblongata on its upper smooth surface.

The exoccipitals, 2, 2, are very irregular subtriangular bones; each is produced backwards into a peduncular process, supporting a moiety of the upper half of the occipital condyle. The outer and fore part of the exoccipital expands into the irregular base of the triangle: it is perforated by a slit for the eighth pair of nerves; it articulates below with the basioccipital; it is excavated in front to lodge the petrosal cartilage, where it articulates with the alisphenoid; it unites above with the superoccipital. The superoccipital, 3, is of a subrhomboidal form, sends a spine from its upper and hinder surface, expands laterally into oblong processes, is notched anteriorly, and sends down two thin plates from its under surface, bounding on the mesial side the surface for the cerebellum, and by the outer side forming the inner and upper parts of the acoustic cavities. The superoccipital articulates below with the exoccipitals and alisphenoids, and in front with the parietal, by which it is overlapped in its whole extent. The occipital vertebra is as if it were sheathed in the expanded posterior outlet of the parietal one (Fig. 17), the centrum resting on the oblique surface of that in front, and the anterior base of the neural spine entering a cavity in and being overlapped by that of the preceding neural spine: the analogy of this kind of "emboitement" of the occipital in the parietal vertebra with the firm interlocking of the ordinary vertebræ of the trunk is very interesting: the end gained seems to be, chiefly, an extra protection of the epencephalon —the most important segment to life of all the primary divisions of the cerebro-spinal axis. The thickness of its immediately protecting walls (formed by the basi-, ex-, and super-occipitals) is equal to that of the same vertebral elements in the human skull, but they are moreover composed of very firm and dense tissue throughout, having no diploë: the epencephalon also derives a further and equally thick bony covering from the basisphenoid and the parietals, the latter being overlapped by the mastoids, which form a third covering to the cerebellum.

The basisphenoid, 5, and presphenoid, 9, form a single bone, and the chief keel of the cranial superstructure. The posterior articular surface looks obliquely upwards and backwards, and supports that of the vertebral centrum behind, as the posterior ball of the ordinary vertebræ supports the oblique cup of the succeeding vertebræ; here, however, all motion is abrogated between the two vertebræ, and the co-adapted surfaces are rough and sutural. The basisphenoid presents a smooth cerebral channel above for the mesencephalon, in front of which a deep depression (sella) sinks abruptly into the expanded part of the bone, and there bifurcates, each fork forming a short cul-de-sac in the substance of the bone.

The alisphenoids, 6, form the anterior half of the fenestra ovalis, which is completed by the exoccipitals; and in their two large perforations for the posterior divisions of the fifth pair of nerves, as well as in their relative size and position, the alisphenoids agree with those of the frog. Each alisphenoid is a thick suboval piece, with a tubercular process on its under and lateral part; it rests upon the basisphenoid and basioccipital, supports the posterior part of the parietal and a portion of the mastoid, 8, and unites anteriorly with the descending lateral plate of the parietal bone.

The parietal, 7, is a large and long, symmetrical, roof-shaped bone, with a median longitudinal crest along its upper surface, where the two originally distinct moieties have coalesced. It is narrowest posteriorly, where it overlaps the superoccipital, and is itself overlapped by the mastoid: it is convex at its middle part on each side of the sagittal spine, and is continued downwards and inwards, to rest immediately upon the basisphenoid. This part of the parietal seems to be formed by an extension of ossification along a membranous space, like that which permanently remains so in the frog, between the alisphenoid and orbitosphenoid: the mesencephalon and the chief part of the cerebral lobes are protected by this unusually developed spine of the mesencephalic vertebra. The optic foramina are conjugational ones, between the anterior border of the lateral plate of the parietal and the posterior border of the corresponding plate of the frontal.

The frontals, 11, rest by descending lateral plates, representing connate orbitosphenoids, 12, upon the attenuated, pointed prolongation of the basisphenoid: the upper surface of each frontal is flat, subquadrate, broader than long in the boa, and the reverse in the python, where the roof the orbit is continued outwards by a detached superorbital bone: there is a distinct, oval, articular surface near the anterior median angle of each frontal to which the prefrontal is attached: the angle itself is slightly produced, to form the articular process for the nasal bones. The smooth orbitosphenoid plate of the frontal joins the outer margin of the upper surface of the frontal at an acute angle; the inner side of each frontal is deeply excavated for the prolongation of the cerebral lobes, and the cavity is converted into a canal by a median vertical plate of bone at the inner and anterior end of the frontal. The frontals join the parietals and postfrontals behind, and, by the anchylosed orbital plates, the presphenoid below, the prefrontals and nasals before, and the superorbitals at their lateral margins. The orbitosphenoids have their bases extended inwards, and meet below the prosencephalon and above the presphenoid, as the neurapophyses of the atlas meet each other above the centrum. The anterior third part of such inwardly-produced base is met by a downward production of the mesial margin of the frontal, forming a septum between the olfactory prolongations of the brain, but is not confluent with the frontal bone: the outer portion of the orbitosphenoids ascends obliquely outwards, and is confluent with the under part of the frontal; it is smooth externally, and deeply notched posteriorly for the optic foramen.

The post-frontal, 12, is a moderately long trihedral bone, articulated by its expanded cranial end to the frontal and parietal, and bent down to rest upon the outer and fore angle of the ectopterygoid. It does not reach that bone in the boa, nor in poisonous serpents. In both the boa and python it receives the anterior sharp angle of the parietal in a notch.

The natural segment which terminates the cranium anteriorly, and is formed by the vomerine, prefrontal, and nasal bones, is very distinct in the ophidians.

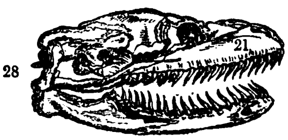
The vomer, 13, is divided, as in salamandroid fishes and batrachians, but is edentulous: each half is a long, narrow plate, smooth and convex below, concave above, with the inner margin slightly raised; pointed anteriorly, and with two processes, and an intervening notch above the base of the pointed end. The prefrontals, 14, are connate with the lacrymals, 73. The two bones which intervene between the vomerine and nasal bones are the turbinals, 19; they are bent longitudinally outwards in the form of a semicylinder about the termination of the olfactory nerves.

The spine of the nasal vertebra is divided symmetrically, as in the frog, forming the nasal bones, 15; they are elongated, bent plates, with the shorter upper part arching outwards and downwards, completing the olfactory canal above, and with a longer median plate, forming a vertical wall, applied closely to its fellow, except in front, where the nasal process of the premaxillary is received in the interspace of the nasals.

The acoustic capsule remains in great part cartilaginous: there is no detached centre of ossification in it; to whatever extent this capsule is ossified, it is by a continuous extension from the alisphenoid. The sclerotic capsule of the eye is chiefly fibrous, with a thin inner layer of cartilage; the olfactory capsule is in a great measure ossified, as above described.

Maxillary Arch.—The palatine, 20, or first piece of this arch, is a strong, oblong bone, having the inner side of its obtuse anterior end applied to the sides of the prefrontals and turbinals, and, near its posterior end, sending a short, thick process upwards and inwards for ligamentous attachment to the lacrymal, and a second similar process outwards as the point of suspension of the maxillary bone. Between these processes the palatine is perforated, and behind them it terminates in a point.

Fig. 14.



SKULL OF BOA CONSTRICTOR.

The chief part of the maxillary, 21 (Fig. 14), is continued forwards from its point of suspension, increasing in depth, and terminating obtusely; a shorter process is also, as usual, continued backwards, and terminates in a point. The point of suspension of the maxillary forms a short, narrow, palatine process. A space occupied by elastic ligament intervenes between the maxillary and the premaxillary, 22, which is single and symmetrical, and firmly wedged into the nasal interspace; the anterior expanded part of this small triangular bone supports two teeth. Thus the bony maxillary arch is interrupted by two ligamentous intervals at the sides of the premaxillary key-bone, in functional relation to the peculiar independent movements of the maxillary and palatine bones required by serpents during the act of engulfing their usually large prey. Two bones extend backwards as appendages to the maxillary arch: one is the "pterygoid," 24, from the palatine; the other the ectopterygoid, 25, from the maxillary. The pterygoid is continued from the posterior extremity of the palatine to abut against the end of the tympanic pedicle; the under part of the anterior half of the pterygoid is beset with teeth. The ectopterygoid, 25, overlaps the posterior end of the maxillary, and is articulated by its posterior-obliquely cut end to the outer surface of the middle expanded part of the pterygoid.

Mandibular Arch.—The tympanic bone, 28 (Figs. 14 and 15), is a strong trihedral pedicle, articulated by an oblique upper surface to the end of the mastoid, and expanded transversely below to form the antero-posteriorly convex, transversely concave, condyle for the lower jaw. This consists chiefly of an articular and a dentary, with a small coronoid and splenial, piece. The articular piece ends obtusely, immediately behind the condyle; it is a little contracted in front of it, and gradually expands to its middle part, sends up two short processes, then suddenly contracts and terminates in a point wedged into the posterior and outer notch of the dentary piece. The articular is deeply grooved above, and produced into a ridge below. The coronoid is a short compressed plate; the splenial is a longer, slender plate, applied to the inner side of the articular and dentary, and closing the groove on the inner side of the latter. The outer side of the dentary offers a single perforation near its anterior end, which is united to that of the opposite ramus by elastic ligament.

By the above-described mode of union of the extremities of the maxillary and mandibular bones, those on the right side can be drawn apart from those on the left, and the mouth can be opened not only vertically, as in other vertebrate animals, but also transversely, as in insects. Viewing the bones of the mouth that support teeth in the great constricting serpents, they offer the appearance of six jaws—four above and two below; the inner pair of jaws above are formed by the palatine and pterygoid bones, the outer pair by the maxillaries, the under pair by the mandibles, or "rami," as they are termed, of the lower jaw.

Each of these six jaws, moreover, besides the movements vertically and laterally, can be protruded and retracted, independently of the other: by these movements the boa is enabled to retain and slowly engulf its prey, which may be much larger than its own body. At the first seizure the head of the prey is held firmly by the long and sharp recurved teeth of all the jaws, whilst the body is crushed by the overlapping coils of the serpent; the death-struggles having ceased, the constrictor slowly uncoils, and the head of the prey is bedewed with an abundant slimy mucus: one jaw is then unfixed, and its teeth withdrawn by being pushed forward, when they are again infixed, further back upon the prey; the next jaw is then unfixed, protruded, and reattached; and so with the rest in succession—this movement of protraction being almost the only one of which they are susceptible whilst stretched apart to the utmost by the bulk of the animal encompassed by them; thus, by their successive movements, it is slowly and spirally introduced into the wide gullet.

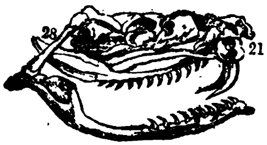
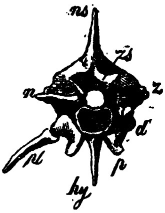


Fig. 15.—SKULL OF A POISONOUS SNAKE.

The bones of the mouth, in the poisonous serpents, have characters distinct from those of the constricting serpents. These characters consist chiefly in the modification of form and attachments of the superior maxillary bone (Fig. 15), 21, which is moveably articulated to the palatine, ectopterygoid, and lacrymal bones; but chiefly supported by the latter, which presents the form of a short, strong, three-sided pedicle, extending from the anterior external angle of the frontal to the anterior and upper part of the maxillary. The articular surface of the maxillary is slightly concave, of an oval shape; the surface articulating with the ectopterygoid on the posterior and upper part of the maxillary is smaller and convex. The maxillary bone is pushed forward and rotated upon the lacrymal joint by the advance of the ectopterygoids, which are associated with the movements of the tympanic pedicle of the lower jaw by means of the true pterygoid bones. The premaxillary bone (Fig. 13), 22, is edentulous. A single, long, perforated poison-fang is anchylosed to the right maxillary, and sometimes two similar fangs, as in the cobra figured in Cut 13. The palatine bones have four or five, and the pterygoids from eight to ten small, imperforate, pointed, and recurved teeth. The frontal bones are broader than they are long; there are no superorbitals. A strong ridge is developed from the under surface of the basisphenoid, and a long and strong recurved hypapophysis from that of the basioccipital; these give insertion to the powerful "longi-colli" muscles by which the downward stroke of the head is performed in the infliction of the wound by the poison-fangs.

The characteristics of the trunk-vertebræ of the ophidian reptiles are as follow:—The autogenous elements, except the pleurapophyses (Fig. 16), *pl*, coalesce with one another in the vertebræ of the trunk; and the pleurapophyses also become anchylosed to the diapophyses in those of the tail. There is no trace of suture between the neural arch (*ib.*), *n*, and centrum, *c*. The outer substance of the vertebra is compact, with a smooth or polished surface. The vertebræ are "procœlian;" that is, they are articulated together by ball-and-socket joints, the socket being on the fore part of the centrum, where it forms a deep cup with its rim sharply defined; the cavity looking not directly forwards, but a little downwards, from the greater prominence of the upper border; the well-turned prominent ball terminates the back part of the centrum rather more obliquely, its aspect being backwards and upwards. The hypapophysis, *hy*, is developed in different proportions from different vertebræ, but throughout the greater part of the trunk presents a considerable size in the cobra and crotalus (Figs. 13 and 16), *hy*; it is shorter in the python and boa. A vascular canal perforates the under surface of the centrum, and there are sometimes two or even three smaller foramina. In the python a large, vertically oblong, but short diapophysis extends from the fore part of the side of the centrum obliquely backwards: it is covered by the articular surface for the rib, convex lengthwise, and convex vertically at its upper half, but slightly concave at its lower half. In the rattlesnake the diapophysis developes a small, circumscribed, articular tubercle, *d*, for the free vertebral rib or pleurapophysis, *pl*; a parapophysis, *p*, extends downwards and forwards below the level of the centrum; the anterior zygapophysis, *z*, seems to be supported by a similar process from the upper end of the diapophysis. The base of the neural arch swells outward from its confluence with the centrum, and developes from each angle a transversely-elongated zygapophysis; that from the anterior angle looking upwards, that from the posterior angle downwards, both surfaces being flat, and almost horizontal, as in the batrachians. The neural canal is narrow; the neural spine, *ns*, is of moderate height, about equal to its antero-posterior extent; it is compressed and truncate. A wedge-shaped process (the "zygosphene"), *zs*, is developed from the fore part of the base of the spine; the lower apex of the wedge being, as it were, cut off, and its sloping sides presenting two smooth, flat, articular surfaces.

Fig. 16.



VERTEBRA OF THE RATTLESNAKE (*Crotalus*).

This wedge is received into a cavity (the "zygantrum") excavated in the posterior expansion of the neural arch, and having two smooth articular surfaces to which the zygosphenal surfaces are adapted.

Thus the vertebræ of serpents articulate with each other by eight joints in addition to those of the cup and ball on the centrum; and interlock by parts reciprocally receiving and entering one another, like the joints called tenon-and-mortice in carpentry. In the caudal vertebræ, the hypapophysis is double, the transition being effected by its progressive bifurcation in the posterior abdominal vertebræ. The diapophyses become much longer in the caudal vertebræ, and support in the anterior ones short ribs which usually become anchylosed to their extremities.

The pleurapophyses or vertebral ribs in serpents have an oblong articular surface, concave above and almost flat below in the python, with a tubercle developed from the upper part, and a rough surface excavated on the fore part of the expanded head for the insertion of the precostal ligament. They have a large medullary cavity, with dense but thin walls, and a fine cancellous structure at their articular ends. Their lower end supports a short cartilaginous hæmapophysis, which is attached to the broad and stiff abdominal scute. These scutes, alternately raised and depressed by muscles attached to the ribs and integument, aid in the gliding movements of serpents; and the ribs, like the legs in the centipede, subserve locomotion; but they have also accessory functions in relation to breathing and constriction. The anterior ribs in the cobra (Fig. 13), *pl*, are unusually long, and are slightly bent; they can be folded back one upon another, and can be drawn forward, or erected, when they sustain a fold of integument, peculiarly coloured in some species—*e.g.*, the spectacled cobra—and which has the effect of making this venomous snake more conspicuous at the moment when it is about to inflict its deadly bite. The ribs commence in the cobra, as in other serpents, at the third vertebra from the head.

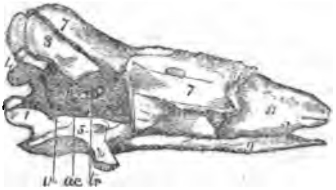
The centrum of the first vertebra coalesces with that of the second, and its place is taken by an autogenous hypapophysis: this, in the python, is articulated by suture to the neurapophyses; it also presents a concave articular surface anteriorly for the lower part of the basioccipital tubercle, and a similar surface behind for the detached central part of the body of the atlas, or "odontoid process of the axis." The base of each neurapophysis has an antero-internal articular surface for the exoccipital tubercle, the middle one for the hypapophysis, and a postero-internal surface for the upper and lateral parts of the odontoid; they thus rest on both the separated parts of their proper centrum. The neurapophyses expand and arch over the neural canal, but meet without coalescing. There is no neural spine. Each neurapophysis developes from its upper and hinder border a short zygapophysis, and from its side a still shorter diapophysis. In the second vertebra, the odontoid presents a convex tubercle anteriorly, which fills up the articular cavity in the atlas for the occipital tubercle; below this is the surface for the hypapophysial part of the atlas, and above and behind it are the two surfaces for the atlantal neurapophyses. The whole posterior surface of the odontoid is anchylosed to the proper centrum of the axis, and in part to its hypapophysis. The neural arch of the axis developes a short ribless diapophysis from each side of its base; a thick sub-bifid zygapophysis from each side of the posterior margin; and a moderately long bent-back spine from its upper part. The centrum terminates in a ball behind, and below this sends downwards and backwards a long hypapophysis.

At the opposite extreme of the elongated body, two or three much simplified vertebræ are usually found blended together. In true serpents there are no scapular arch and appendages, no sternum, no sacrum; but a pair of slender bones, often supporting a second bone, armed with a claw, are found suspended on the flesh near the vent. The exposed parts of these appendages are called "anal hooks;" the parts themselves, like the similarly suspended ventral fins of the pike, are rudiments of hind limbs.

Serpents have been regarded as animals degraded from a higher type; but their whole organization, and especially their bony structure, demonstrate that their parts are as exquisitely adjusted to the form of their whole, and to their habits and sphere of life, as is the organization of any animal which we call superior to them. It is true that the serpent has no limbs, yet it can outclimb the monkey, outswim the fish, outleap the jerboa, and, suddenly loosing the close coils of its crouching spiral, it can spring into the air and seize the bird upon the wing: all these creatures have been observed to fall its prey. The serpent has neither hands nor talons, yet it can outwrestle the athlete and crush the tiger in the embrace of its ponderous overlapping folds. Instead of licking up its food as it glides along, the serpent uplifts its crushed prey, and presents it, grasped in the death-coil as in a hand, to its slimy gaping mouth.

It is truly wonderful to see the work of hands, feet, and fins performed by a modification of the vertebral column—by a multiplication of its segments with mobility of its ribs. But the vertebræ are specially modified, as we have seen, to compensate, by the strength of their numerous articulations, for the weakness of their manifold repetition, and the consequent elongation of the slender column. As serpents move chiefly on the surface of the earth, their danger is greatest from pressure and blows from above; all the joints are fashioned accordingly to resist yielding, and sustain pressure in a vertical direction; there is no natural undulation of the body upwards and downwards—it is permitted only from side to side. So closely and compactly do the ten pairs of joints between each of the two hundred or three hundred vertebræ fit together, that even in the relaxed and dead state the body cannot be twisted except in a series of side coils. In the construction of the skull, which has merited a description in some detail, and well deserves a close study, the thickness and density of the cranial bones must strike the mind as a special provision against fracture and injury to the brain. When we contemplate the still more remarkable manner in which these bones are applied, one over another, the superoccipital (Fig. 17), 3, overlapping the exoccipital, 4, and the parietal, 7, overlapping the superoccipital,—the natural segments or vertebræ of the cranium being sheathed, one within the other, like the corresponding segments in the trunk, —we cannot but discern a special adaptation in the structure of serpents to their commonly prone position, and a provision, exemplified in such structure, of the dangers to which they would be subject from falling bodies and the tread of heavy beasts. Many other equally beautiful instances of design might be cited from the organization of serpents, in relation to the necessities of their apodal vermiform character; just as the snake-like eel is compensated by analogous modifications amongst fishes, and the snake-like centipede among insects.

Fig. 17.



SECTION OF SKULL, BOA CONSTRICTOR.

Osteology of Lizards.—The transition from the ophidian, or snake-like, to the lacertian, or lizard-like reptiles, is very gradual and easy, if we pass from the serpents with fixed jaws and a scapular arch—as, *e. g.*, the slow-worms (*anguis*)—to the serpentiform lizards with mere rudiments of limbs—as, *e. g.*, the pseudopus. The distinction is effected through the establishment of a costal arch in the trunk, completed by the addition of a hæmal spine (sternum) and hæmapophyses (sternal ribs) to the pleurapophyses or vertebral ribs, which are alone ossified in ophidia.

The vertebræ of the trunk have the same procœlian character, *i. e.* with the cup anterior and the ball behind; the latter being usually less prominent, more oblique, and more transversely oval than in serpents. The vertebræ also are commonly larger, and always fewer in number than in the typical ophidia. The ribs do not begin to be developed so near the head in lizards. Not only the atlas and dentata, but sometimes, as in the monitor (*varanus*), the four following vertebræ are devoid of pleurapophyses; and when these first appear they are short, and sometimes (as in *cyclodus*) expanded at their extremities. They rapidly elongate in succeeding vertebræ, and usually at the ninth from the head (*cyclodus*, *iguana*), or tenth (*varanus*), they are joined through the medium of ossified hæmapophyses to the sternum; two (*varanus*), three (*chameleo*, *iguana*), or four (*cyclodus*), following vertebræ are similarly completed; and then the hæmapophyses are either united below without intervening sternum (*chameleo*), or two or three of them are joined by a common cartilage to the cartilaginous end of the sternum. The hæmapophyses afterwards project freely, and are reduced to short appendages to the pleurapophyses. These also shorten, and sometimes suddenly, as, *e. g.*, after the eighteenth vertebra in the monitors (*varanus*), in which they end at the twenty-eighth vertebra, as they began, viz., in the form of short straight appendages to the diapophyses.

The flying lizard (*Draco volans*), is so called on account of the wing-like expansions from the sides of its body, supported, like the hood of the cobra, by slender elongated ribs. In this little lizard there are twenty vertebræ supporting moveable ribs, which commence apparently at the fifth. Those of the eighth vertebra first join the sternum, as do those of the ninth and tenth; the pleurapophyses of the eleventh vertebra suddenly acquire extreme length; those of the five following vertebræ are also long and slender; they extend outwards and backwards, and support the parachute formed by the broad lateral fold of the abdominal integuments. The pleurapophyses of the seventeenth vertebra become suddenly shorter, and these elements progressively diminish to the sacrum: this consists of two vertebræ, modified as in other lizards. There are about fifty caudal vertebræ.

The semi-ossified sternum in the iguana has a median groove and fissure, and readily separates into two lateral moieties. The long stem of the episternum covers the outer part of the groove, where it represents the *keel* of the sternum in birds.

In the skull of the lizard order we first meet with a second bony bar, diverging from the maxillary arch backwards, and abutting against the mastoid, and sometimes also against the tympanic and postfrontal. This bar is called the "zygomatic arch;" it usually consists of two bones—the one next the maxillary is the "malar," 26, the one next the mastoid is the "squamosal," 27; it assumes a form meriting that name in the tortoise, and first received it, as "pars squamosa," in man, where it is not only like a great scale, but becomes confluent with both the mastoid and tympanic. But, as has been before remarked, we must use the terms invented by anthropotomists as arbitrary signs of the corresponding bones in the lower creation.

The scapula in the monitor (*varanus*) is a triangular plate with a convex base, a concave hind border, and a nearly straight front border; the apex is thick and truncate, with an oval surface divided into two facets. The hind border forms a part of the glenoid cavity; the front one is a rough epiphysial surface, continuous with a similar but narrower tract, extending upon the anterior border, and by which the scapula articulates with the coracoid. In the iguanians and scincoids this synchondrosis is obliterated, and the two bones are confluent. The hind border of the scapula is nearly straight—the front one sends forwards a process dividing it into two deep marginations.

The coracoid in both the varanus and iguana is short and broad; its main body, which articulates with the sternum, is shaped like an axe-blade, and two strong, straight, compressed processes extend forwards from its neck, which is perforated between the origins of these processes and the part forming the glenoid articulations.

The clavicles are simple sigmoid styles in the varanus and iguana; are bent upon themselves, like the Australian boomerang, in the cyclodus; and have the median part of the bend expanded and perforated in lacerta and scincus. They are absent in the chameleon.

The sacral vertebræ retain, in some lacertians, the cup-and-ball joints; and in these—*e. g.*, the scincoids—in which the centrums coalesce, the hind end of the second presents a ball to the first caudal—not a cup, as in the crocodile. In the cyclodus the thick, short, straight pleurapophyses are distinct at their origins from the two coalesced centrums, but coalesce at their ends, that of the first sacral being the thickest. In varanus and iguana the pleurapophyses, as well as the centrums, retain their distinctness, but the hinder ribs incline forwards and touch the expanded ends of the fore pair. These ends are very thick, and are scooped out obliquely behind, so as to present a curved border to the ilium, which Cuvier compares to a horse-shoe.

In the varanus and iguana the pleurapophyses of the first caudal incline backwards as much as those of the second sacral do forwards. In the cyclodus they extend outwards, parallel with those of the sacral vertebræ, and are longitudinally grooved beneath. Hæmapophyses are wanting in the first caudal, are developed in the second, and are displaced to the interval between this and the third; they are confluent at their distal end, and produced into a long spine. At the twelfth tail-vertebra the line is obvious that indicates the extent of the anterior detached piece, or epiphysis, of the centrum, immediately in front of the origin of the diapophyses; it continues marking off the anterior third of the centrum in all the other caudals. At this line the tail snaps off, when a lizard escapes by the common ruse of leaving the part of the tail by which it has been seized in the hands of the baffled pursuer. It is a very curious character, and quite peculiar to the lacertians—this ossification of the centrum from two points and their incomplete coalescence: it adds nothing to the power of bending, or to any other action of the tail, but indicates a prevision of the liability to their being caught by their long tail, and may be interpreted as a provision for their escape. The neural arch has coalesced with the centrum throughout the tail: the epiphysial line does not extend through that arch; but its thin and brittle walls soon break, when the two parts of the centrum are forcibly separated.

Lizards, as is well known, have the power of reproducing the tail, but the vertebral axis is never ossified in the new-formed part.

Osteology of Crocodiles.—The numerous and varied forms of fossil bones of extinct reptiles derive most elucidation from the skeleton of the higher organized sauria of Cuvier, which now are rightly held to constitute a distinct order, called *Loricata* or *Crocodilia:* a more complete description, therefore, will be given of the skeleton of a member of this order than was deemed needful in regard to the lacertian group of sauria.

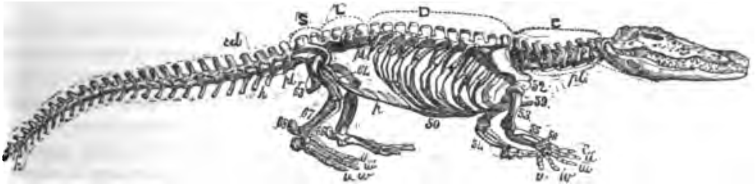
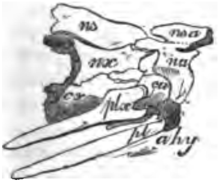


Fig. 18.—SKELETON OF THE CROCODILE (*Crocodilus niloticus*).

Fig. 19.



ATLAS AND AXIS VERTEBRÆ OF THE CROCODILE.

Commencing with the trunk, the first and second vertebræ of the neck are peculiarly modified in most air-breathing vertebrata, and have accordingly received the special names, the one of "atlas," the other of "axis." In comparative anatomy these become arbitrary terms, the properties being soon lost which suggested those names to the human anatomist; the "atlas," *e.g.*, has no power of rotation upon the "axis," in the crocodile, and it is only in the upright skeleton of man that the large globular head is sustained upon the shoulder-like processes of the "atlas." In the crocodile, these vertebræ are concealed by the peculiarly prolonged angle of the lower jaw in the side view of the skeleton (Fig. 18), and a figure of the two vertebræ is therefore subjoined (Fig. 19). The pleurapophyses, *pl*, are retained in both segments, as in all the other vertebræ of the trunk. That of the atlas, *pl*, *a*, is a simple slender style, articulated by the head only, to the "hypapophysis," *ahy*. The neurapophyses, *na*, of the atlas retain their primitive distinctness; each rests in part upon the proper body of the atlas, *ca*, in part upon the hypapophysis. The neural spine, *ns*, *a*, is also here an independent part, and rests upon the upper extremities of the neurapophyses. It is broad and flat, and prepares us for the further metamorphosis of the corresponding element in the cranial vertebræ.

The centrum of the atlas, *ca*, called the "odontoid process of the axis" in human anatomy, here supports the abnormally-advanced rib of the axis vertebra, *pl*, *x*. The proper centrum of the axis vertebra, *cx*, is the only one in the cervical series which does not support a rib; it articulates by suture with its neurapophyses, *nx*, and is characterized by having its anterior surface flat, and its posterior one convex.

With the exception of the two sacral vertebræ, the bodies of which have one articular surface flat and the other concave, and of the first caudal vertebra, the body of which has both articular surfaces convex, the bodies of all the vertebræ beyond the axis have the anterior articular surface concave, and the posterior one convex, and articulate with one another by ball-and-socket joints. This type of vertebra, which I have termed "procœlian" (προς, before, κοιλος, concave), characterizes all the existing genera and species of the order *Crocodilia* with all the extinct species of the tertiary periods, and also two extinct species of the green-sand formation in New Jersey.*

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* "Quarterly Journal of the Geological Society," November, 1849.

Here, so far as our present knowledge extends, the type was lost, and other dispositions of the articular surfaces of the centrum occur in the vertebræ of the crocodilia of the older secondary formations. The only known crocodilian genus of the periods antecedent to the chalk and green-sand deposits with vertebræ articulated together by ball-and-socket joints, have the position of the cup and the ball the reverse of that in the modern crocodiles, and one genus, thus characterized by vertebræ of the "opisthocœlian" type (οπισθος, behind, κοιλος, concave), has accordingly been termed streptospondylus, signifying "vertebræ reversed." But the most prevalent type of vertebra amongst the crocodilia of the secondary periods was that in which both articular surfaces of the centrum were concave, but in a less degree than in the single concave surface of the vertebræ united by ball and socket. Vertebræ of this "amphicœlian" type (αμφι, both, κοιλος, concave) existed in the teleosaurus and steneosaurus. In the ichthyosaurus the concave surfaces are usually deepened to the extent and in the form shown in those of the fish (Cut 8). Some of the most gigantic of the crocodilia of the secondary strata had one end of the vertebral centrum flattened, and the other (hinder) end concave; this "platycœlian" type (πλατυς, flat, κοιλος, concave) we find in the dorsal and caudal vertebræ of the gigantic cetiosaurus.

With a few exceptions, all the modern reptiles of the order lacertilia have the same procœlian type of vertebræ as the modern crocodilia, and the same structure prevailed as far back as the period of the mosasaurus, and in some smaller members of the lacertilian order in the cretaceous and wealden epochs.

Resuming the special description of the osteology of the modern crocodilia, we find the procœlian type of centrum established in the third cervical, which is shorter but broader than the second; a parapophysis is developed from the side of the centrum, and a diapophysis from the base of the neural arch; the pleurapophysis is shorter, its fixed extremity is bifid, articulating to the two above-named processes; its free extremity expands, and its anterior angle is directed forwards to abut against the inner surface of the extremity of the rib of both the axis and atlas, whilst its posterior prolongation overlaps the rib of the fourth vertebra. The same general characters and imbricated coadaptation of the ribs (Fig. 18), *pl*, characterize the succeeding cervical vertebræ to the seventh inclusive, the hypapophysis progressively thoughth slightly increasing in size. In the eighth cervical the rib becomes elongated and slender; the anterior angle is almost or quite suppressed, and the posterior one more developed and produced more downwards, so as to form the body of the rib, which terminates, however, in a free point. In the ninth cervical, the rib is increased in length, but is still what would be termed a "false" or "floating rib" in anthropotomy.

In the succeeding vertebra the pleurapophysis articulates with a hæmapophysis, and the hæmal arch is completed by a hæmal spine; and by this completion of the typical segment we distinguish the commencement of the series of dorsal vertebræ (*ib.*), D. With regard to the so-called "perforation of the transverse process" this equally exists in the present vertebra, as in the cervicals; on the other hand, the cervical vertebræ equally show surfaces for the articulation of ribs. The typical characters of the segment, due to the completion of both neural and hæmal arches, are continued in some species, of crocodilia to the sixteenth, in some (*crocodilus acutus*) to the eighteenth vertebra. In the *crocodilus acutus* and the *alligator lucius* the hæmapophysis of the eighth dorsal rib (seventeenth segment from the head) joins that of the antecedent vertebra. The pleurapophyses project freely outwards, and become "floating ribs" in the eighteenth, nineteenth, and twentieth vertebræ, in which they become rapidly shorter, and in the last appear as mere appendages to the end of the long and broad diapophyses: but the hæmapophyses by no means disappear after the solution of their union with their pleurapophyses; they are essentially independent elements of the segment, and they are continued, therefore, in pairs along the ventral surface of the abdomen of the crocodilia, as far as their modified homotypes the pubic bones. They are more or less ossified, and are generally divided into two or three pieces.

The lumbar vertebræ are those in which the diapophyses cease to support moveable pleurapophyses, although they are elongated by the coalesced rudiments of such which are distinct in the young crocodilia. The length and persistent individuality of more or fewer of these rudimental ribs determines the number of the dorsal and lumbar vertebræ respectively, and exemplifies the purely artificial character of the distinction. The number of vertebræ or segments between the skull and the sacrum, in all the crocodilia I have yet examined, is twenty-four. In the skeleton of a gavial I have seen thirteen dorsal and two lumbar; in that of a crocodilus cataphractus twelve dorsal and three lumbar; in those of a crocodilus acutus and alligator lucius, eleven dorsal and four lumbar, and this is the most common number; but in the skeleton of the crocodile, probably the species called croc. biporcatus, described by Cuvier, he gives five as the number of the lumbar vertebræ. But these varieties in the development or coalescence of the stunted pleurapophysis are of little essential moment; and only serve to show the artificial character of the "dorsal" and "lumbar" vertebræ. The coalescence of the rib with the diapophysis obliterates of course the character of the "costal articular surfaces," which we have seen to be common to both dorsal and cervical vertebræ. The lumbar zygapophyses have their articular surfaces almost horizontal, and the diapophyses, if not longer, have their antero-posterior extent somewhat increased; they are much depressed, or flattened horizontally.

The sacral vertebræ are very distinctly marked by the flatness of the coadapted ends of their centrums; there are never more than two such vertebræ in the crocodilia recent or extinct: in the first the anterior surface of the centrum is concave; in the second it is the posterior surface; the zygapophyses are not obliterated in either of these sacral vertebræ, so that the aspects of their articular surface—upwards in the anterior pair, downwards in the posterior pair—determines at once the corresponding extremity of a detached sacral vertebra. The thick and strong transverse processes form another characteristic of these vertebræ; for a long period the suture near their base remains to show how large a proportion is formed by the pleurapophysis. This element articulates more with the centrum than with the diapophysis developed from the neural arch; it terminates by a rough, truncate, expanded extremity, which almost or quite joins that of the similarly but more expanded rib of the other sacral vertebræ. Against these extremities is applied a supplementary costal piece, serially homologous with the appendage to the proper pleurapophysis in the dorsal vertebræ, but here interposing itself between the pleurapophyses and hæmapophyses of both sacral vertebræ, not of one only. This intermediate pleurapophysial appendage is called the "ilium;" it is short, thick, very broad, and subtriangular, the lower truncated apex forming with the connected extremities of the hæmapophysis an articular cavity for the diverging appendage, called the "hind leg." The hæmapophysis of the anterior sacral vertebra is called "pubis," 64; it is moderately long and slender, but expanded and flattened at its lower extremity, which is directed forwards towards that of its fellow, and joined to it through the intermedium of a broad, cartilaginous, hæmal spine, completing the hæmal canal. The posterior hæmapophysis, 63, is broader, subdepressed, and subtriangular, expanding as it approaches its fellow to complete the second hæmal arch; it is termed "ischium." The great development of all the elements of these hæmal arches, and the peculiar and distinctive forms of those that have thereby acquired, from the earliest dawn of anatomical science, special names, relates physiologically to the functions of the diverging appendage which is developed into a potent locomotive member. This limb appertains properly, as the proportion contributed by the ischium to the articular socket and the greater breadth of the pleurapophysis show, to the second sacral vertebra; to which the ilium chiefly belongs.

The first caudal vertebra, which presents a ball for articulating with a cup on the back part of the last sacral, retains, nevertheless, the typical position of the ball on the back part of the centrum; it is thus biconvex, and the only vertebra of the series which presents that structure.

The first caudal vertebra, moreover, is distinguished from the rest by having no articular surfaces for the hæmapophyses, which in the succeeding caudals form a hæmal arch, like the neurapophyses above, by articulating directly with the centrum. The arch so formed has its base not applied over the middle of a single centrum, but, like the neural arch in the back of the tortoise and sacrum of the bird, across the interspace between two centrums. The first hæmal arch of the tail belongs, however, to the second caudal vertebra, but it is displaced a little backwards from its typical position.

The caudal hæmapophyses, *h h*, coalesce at their lower or distal ends, from which a spinous process is prolonged downwards and backwards; this grows shorter towards the end of the tail, but is compressed and somewhat expanded antero-posteriorly. The hæmal arch so constituted has received the name of "chevron bone."

It is very true, as Cuvier said in the last lecture he delivered, "if we were agreed as to the crocodile's head, we should be so as to that of other animals; because the crocodile is intermediate between mammals, birds, and fishes." Accordingly, the following description of the crocodile's skull is coextensive with that of the fish; if the answerable bones are rightly determined between these, their correspondence with those of other vertebrates will be facilitated. The difficulties in comprehending the nature of some of the bones of the crocodile's head have arisen through passing to its comparison from that of the mammal's skull—by descending instead of ascending to it.

The segments composing the skull are more modified than those of the pelvis; but just as the vertebral pattern is best preserved in the neural arches of the pelvis, which are called collectively "sacrum," so, also, is it in the same arches of the skull, which are called collectively "cranium. The elements of which these cranial arches are composed preserve, moreover, their primitive or normal individuality more completely than in any of the vertebræ of the trunk, except the atlas, and consequently the archetypal character can be more completely demonstrated.*

If, after separating the atlas from the occiput, we proceed to detach the occipital segment of the cranium from the next segment in advance, we find the detached segment presenting the form and structure of the neural arch. The "centrum" presents, like those of the trunk, a convexity or ball at its posterior articular surface, but its anterior one, like the hindmost centrum of the sacrum, unites with the next centrum in advance by a flat rough "sutural" surface. Like most of the centrums in the neck and beginning of the back, that of the occiput developes a hypapophysis, but this descending process is longer and larger, its base extending over the whole of the under surface of the centrum. It is a character whereby the occipital centrum of a crocodilian reptile may be distinguished from that of a lacertian one; for in the latter a pair of diverging hypapophyses project from the under surface, as is shown in most recent lizards and in the great extinct mosasaurus.

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* The skull of the crocodile, partially disarticulated, and with the bones numbered as in the following description, may be had of Mr. Flower, No. 22, Lambeth Terrace, Lambeth Road.

The upper and lateral parts of No. 1 present rough sutural surfaces, like those in the centrums of the trunk, for articulating with the "neurapophyses," Nos. 2, 2, which develope short, thick, obtuse, transverse processes, 4, 4. The modified or specialized character of the elements of the cranial vertebræ has gained for them special names. The centrum, 1, is called, as in fishes and all other vertebrates, the "basioccipital;" the neurapophyses, 2, 2, are the "exoccipitals;" the neural spine, 3, is the "superoccipital." The transverse processes, 4, 4, which may combine both diapophyses and parapophyses, are called the "paroccipitals;" they are never detached bones in the crocodilia, as they are in the chelonia and in most fishes. The exoccipitals perform the usual functions of neurapophyses, and, like those of the atlas, meet above the neural canal; they are perforated to give exit to the vagal and hypoglossal nerves, and protect the sides of the medulla oblongata and cerebellum—the two divisions of the epencephalon. The superoccipital, 3, is broad and flat, like the similarly detached neural spine of the atlas; it advances a little forwards, beyond its sustaining neurapophyses, to protect the upper surface of the cerebellum; it is traversed by tympanic air-cells, and assists with the exoccipitals, 2, 2, in the formation of the chamber for the internal ear.

The chief modification of the occipital segment of the skull, as compared with that of the osseous fish, or with the typical vertebra, is the absence of an attached hæmal arch. We shall afterwards see that this arch is present in the crocodile, although displaced backwards.

Proceeding with the neural arches of the crocodile's skull, if we dislocate the segment in advance of the occiput, we bring away, in connection with the long base-bone, 5, the bone, 9, which in the figure of the section of the serpent's skull (Cut 17) is shown similarly united to 5. In fact, the centrums of the vertebræ have here coalesced, as we find to happen in the neck of the siluroid fishes, and in the sacrum of birds and mammals. The two connate cranial centrums must be artificially divided, in order to obtain the segments distinct to which they belong. The hinder portion, 5, of the great base-bone, which is the centrum of the parietal vertebra, is called "basisphenoid." It supports that part of the "mesencephalon," which is formed by the lobe of the third ventricle, and its upper surface is excavated for the pituitary prolongation of that cavity. The basisphenoid developes from its under surface a "hypapophysis," which is suturally united with the fore part of that of the basioccipital, but extends further down, and is similarly united in front to the "pterygoids," 24. These rough sutural surfaces of the long descending process of the basisphenoid are very characteristic of that centrum, when detached, in a fossil state. The neurapophyses of the parietal vertebra, 6, 6, or the "alisphenoids," protect the sides of the mesencephalon, and are notched at their anterior margin, for a conjugational foramen transmitting the trigeminal nerve. As accessory functions they contribute, like the corresponding bones in fishes, to the formation of the ear-chamber. They have, however, a little retrograded in position, resting below in part upon the occipital centrum, and supporting more of the spine of that segment, 3, than of their own, 7. The spine of the parietal vertebra is a permanently distinct, single, depressed bone, like that of the occipital vertebra; it is called the "parietal," and completes the neural arch, as its crown or key-bone; it is partially excavated by the tympanic air-cells, and overlaps the superoccipital. The bones, 8, 8, wedged between 6 and 7, manifest more of their diapophysial character than their homotypes, 4, 4, do in the occipital segment, since they support modified ribs, are developed from independent centres, and preserve their individuality. They form no part of the inner walls of the cranium, but send outwards and backwards a strong transverse process for muscular attachment. They afford a ligamentous attachment to the hæmal arch of their own segment, and articulate largely with the pleurapophyses, 28, of the antecedent hæmal arch, whose more backward displacement, in comparison with its position in the fish's skull, is well illustrated in the metamorphosis of the toad and frog.

On removing the neural arch of the parietal vertebra, after the section of its confluent centrum, the elements of the corresponding arch of the frontal vertebra present the same arrangement. The compressed produced centrum has its form modified like that of the vertebral centrums at the opposite extreme of the body in many birds; it is called the "presphenoid." The neurapophyses, 10, 10, articulate with the upper part of 9; they are expanded, and smoothly excavated on their inner surface to support the sides of the large prosencephalon; they dismiss the great optic nerves by a notch. They show the same tendency to a retrograde change of position as the neighbouring neurapophyses, 6; for though they support a greater proportion of their proper spine, 11, they also support part of the parietal spine, 7, and rest, in part, below upon the parietal centrum, 5: the neurapophyses, 10, 10, are called "orbitosphenoids." The neural spine, 11, of the frontal vertebra retains its normal character as a single symmetrical bone, like the parietal spine which it partly overlaps; it also completes the neural arch of its own segment, but is remarkably extended longitudinally forwards, where it is much thickened, and assists in forming the cavities for the eye-balls; it is called the "frontal" bone.

In contemplating in the skull itself, or such side view as is given in Fig. 9, p. 22, of my work on the Archetype Skeleton, the relative position of the frontal, 11, to the parietal, 7, and of this to the superoccipital, 3, which is overlapped by the parietal, just as itself overlaps the flattened spine of the atlas, we gain a conviction which cannot be shaken by any difference in their mode of ossification, by their median bipartition, or by their extreme expansion in other animals, that the above-named single, median, imbricated bones, each completing its neural arch, and permanently distinct from the piers of such arch, must repeat the same element in those successive arches—in other words, must be "homotypes," or serially homologous. In like manner the serial homology of those piers, called "neurapophyses," viz., the laminæ of the atlas, the exoccipitals, the alisphenoids, and the orbitosphenoids, is equally unmistakable. Nor can we shut out of view the same serial relationship of the paroccipitals, as coalesced diaphophyses of the occipital vertebra, with the mastoids 8, and the postfrontals, 12, as permanently detached diapophyses of their respective vertebræ. All stand out from the sides of the cranium, as tranverse processes for muscular attachment; all are alike autogenous in the turtles; and all of them, in fishes, offer articular surfaces for the ribs or hæmal arches of their respective vertebræ; and these characters are retained in the postfrontals as well as in the mastoids of the crocodiles.

The frontal diapophysis, 12, is wedged between the back part of the spine, 11, and the neurapophysis, 10; its outwardly projecting process extends also backwards, and joins that of the succeeding diapophysis, 8; but, notwithstanding the retrogradation of the inferior arch, it still articulates with part of its own pleurapophysial element, 28, which forms the proximal element of that arch.

There finally remain in the cranium of the crocodile, after the successive detachment of the foregoing arches, the bones terminating the fore-part of the skull; but, notwithstanding the extreme degree of modification to which their extreme position subjects them, we can still trace in their arrangement a correspondence with the vertebrate type.

A long and slender symmetrical grooved bone, 13, between 24 and 24, like the ossified inferior half of the capsule of the notochord, is continued forwards from the inferior part of the centrum, 9, of the frontal vertebra, and stands in the relation of a centrum to the vertical plates of bone, 14, which expand as they rise into a broad, thick, triangular plate, with an exposed horizontal superior surface. These bones, which are called "prefontals," stand in the relation of "neurapophyses" to the rhinencephalic prolongations of the brain commonly but erroneously called "olfactory nerves;" and they form the piers or haunches of a neural arch, which is completed above by a pair of symmetrical bones, 15, called "nasals," which I regard as a divided or bifid neural spine.

The centrum of this arch is established by ossification in the expanded anterior prolongation of the fibrous capsule of the notochord, beyond the termination of its gelatinous axis. The median portion above specified retains most of the formal characters of the centrum; but there is a pair of long, slender, symmetrical ossicles, which, from the seat of their original development, and their relative position to the neural arch, must be regarded as also parts of its centrum. And this ossification of the element in question from different centres will be no new or strange character to those who recollect that the vertebral body in man and mammalia is developed from three centres. The term "vomer" is applied to the pair of bones, 13, because their special homology with the single median bone, so called in fishes and mammals, is indisputable; but a portion of the same element of the skull retains its single symmetrical character in the crocodile, and is connate with the enormous pterygoids, 24, between which it is wedged. In some alligators (*all. niger*) the divided anterior vomer extends far forwards, expands anteriorly, and appears upon the bony palate.

Almost all the other bones of the head of the crocodile are adjusted so as to constitute four inverted arches. These are the hæmal arches of the four segments or vertebræ, of which the neural arches have been just described. But they have been the seat of much greater modifications, by which they are made subservient to a variety of functions unknown in the hæmal arches of the rest of the body. Thus the two anterior hæmal arches of the head perform the office of seizing and bruising the food; are armed for that purpose with teeth: and, whilst one arch is firmly fixed, the other works upon it like the hammer upon the anvil. The elements of the fixed arch, called "maxillary arch," have accordingly undergone the greatest amount of morphological change, in order to adapt that arch to its share in mastication, as well as for forming part of the passage for the respiratory medium, which is perpetually traversing this hæmal canal in its way to purify the blood. Almost the whole of the upper surface of the maxillary arch is firmly united to contiguous parts of the skull by rough or sutural surfaces, and its strength is increased by bony appendages, which diverge from it to abut against other parts of the skull. Comparative anatomy teaches that, of the numerous places of attachment, the one which connects the maxillary arch by its element, 20, with the centrum, 13, and the descending plates of the neurapophyses, 14, of the nasal segment, is the normal or the most constant point of its suspension, the bone, 20, being the pleurapophysial element of the maxillary arch: it is called the "palatine," because the under surface forms a portion of the bony roof of the mouth, called the "palate." It is articulated at its fore part with the bone, 21, in the same plates, which bone is the hæmapophysial element of the maxillary arch: it is called the "maxillary," and is greatly developed both in length and breadth; it is connected not only with 20 behind, and 22 in front, which are parts of the same arch, and with the diverging appendages of the arch, viz., 26, the malar bone, and 24, the pterygoid, but also with the nasals, 15, and the lacrymal, 16, as well as with its fellow of the opposite side of the arch. The smooth, expanded horizontal plate, which effects the latter junction, is called the palatal plate of the maxillary; the thickened external border, where this plate meets the external rough surface of the bone, and which is perforated for the lodgment of the teeth, is the "alveolar border" or "process" of the maxillary. The hæmal spine or key-bone of the arch, 22, is bifid, and the arch is completed by the symphysial junction of the two symmetrical halves; these halves are called "premaxillary bones:" these bones, like the maxillaries, have a rough facial plate, and a smooth palatal plate, with the connecting alveolar border. The median symphysis is perforated vertically through both plates; the outer or upper hole being the external nostril, the under or palatal one being the prepalatal or naso-palatal aperture.

Both the palatine and the maxillary bones send outwards and backwards parts or processes which diverge from the line of the hæmal arch, of which they are the chief elements; and these parts give attachment to distinct bones which form the "diverging appendages" of the arch, and serve to attach it, as do the diverging appendages of the thoracic hæmal arches in the bird, to the succeeding arch.

The appendage, 24, called "pterygoid," effects a more extensive attachment, and is peculiarly developed in the crocodilia. As it extends backwards it expands, unites with its fellow below the nasal canal, and encompassing that canal, coalesces above it with the vomer, and is firmly attached by suture to the presphenoid and basisphenoid: it surrounds the hinder or palatal nostril, and, extending outwards, it gives attachment to a second bone, 25, called "ectopterygoid," which is firmly connected with the maxillary, 25, the malar, 26, and the post-frontal, 12. The second diverging ray is of great strength; it extends from the maxillary, 21 ("hæmapophysis" of the maxillary arch), to the tympanic, 28 ("pleurapophyses" of the mandibular arch), and is divided into two pieces, the malar, 26, and the squamosal, 27. Such are the chief crocodilian modifiations of the hæmal arch, and appendages of the anterior or nasal vertebra of the skull.

The hæmal arch of the frontal vertebra is somewhat less metamorphosed, and has no diverging appendage. It is slightly displaced backwards, and is articulated by only a small proportion of its pleurapophysis, 28, to the parapophysis, 12, of its own segment; the major part of that short and strong rib articulating with the parapophysis, 8, of the succeeding segment. The bone, 28, called "tympanic," because it serves to support the "drum of the ear" in air-breathing vertebrates, is short, strong, and immoveably wedged, in the crocodilia, between the paroccipital, 4, mastoid, 8, post-frontal, 12, and squamosal, 27; and the conditions of this fixation of the pleurapophysis are exemplified in the great development of the hæmapophysis (mandible), which is here unusually long, supports numerous teeth, and requires, therefore, a firm point of suspension, in the violent actions to which the jaws are put in retaining and overcoming the struggles of a powerful living prey. The moveable articulation between the pleurapophysis, 28, and the rest of the hæmal arch is analogous to that which we find between the thoracic pleurapophysis and hæmapophysis in the ostrich and many other birds. But the hæmopophysis of the mandibular arch in the crocodiles is subdivided into several pieces, in order to combine the greatest elasticity and strength with a not excessive weight of bone. The different pieces of this purposely subdivided element have received definite names. That numbered 29, which offers the articular concavity to the convex condyle of the tympanic, 28, is called the "articular" piece; that beneath it, 30, which developes the angle of the jaw, when this projects, is the "angular" piece; the piece above, 29′, is the "surangular;" the thin, broad, flat piece, 31, applied, like a splint, to the inner side of the other parts of the mandible, is the "splenial;" the small accessory ossicle, 31′, is the "coronoid," because it developes the process, so called, in lizards; the anterior piece, 32, which supports the teeth, is called the "dentary." This latter is the homotype of the premaxillary, or it represents that bone in the mandibular arch, of which it may be regarded as the hæmal spine; the other pieces are subdivisions of the hæmapophysial element. The purport of this subdivision of the lower jaw-bone has been well explained by Conybeare * and Buckland,† by the analogy of its structure to that adopted in binding together several parallel plates of elastic wood or steel to make a crossbow, and also in setting together thin plates of steel in the springs of carriages. Dr. Buckland adds—"Those who have witnessed the shock given to the head of a crocodile by the act of snapping together its thin long jaws, must have seen how liable to fracture the lower jaw would be, were it composed of one bone only on each side." The same reasoning applies to the composite structure of the long tympanic pedicle in fishes. In each case the splicing and bracing together of thin flat bones of unequal length and of varying thickness, affords compensation for the weakness and risk of fracture that would otherwise have attended the elongation of the parts. In the abdomen of the crocodile the analogous subdivision of the hæmapophyses, there called abdominal ribs, allows of a slight change of their length, in the expansion and contraction of the walls of that cavity; and since amphibious reptiles, when on land, rest the whole weight of the abdomen directly upon the ground, the necessity of the modification for diminished liability to fracture further appears. These analogies are important, as demonstrating that the general homology of the elements of a natural segment of the skeleton is not affected or obscured by their subdivision for a special end. Now this purposive modification of the hæmapophyses of the frontal vertebra is but a repetition of that which affects the same elements in the abdominal vertebræ.

Passing next to the hæmal arch of the parietal vertebra, we are first struck by its small relative size. Its restricted functions have not required it to grow in proportion with the other arches, and it consequently retains much of its embryonic dimensions. It consists of a ligamentous "stylohyal," its pleurapophysis retaining the same primitive histological condition which obstructs the ordinary recognition of the same elements of the lumbar hæmal arches. A cartilaginous "epihyal," 39, intervenes between this and the ossified "hæmapophysis," 40, which bears the special name of ceratohyal. The hæmal spine, 41, retains its cartilaginous state, like its homotypes, in the abdomen; there they get the special name of "abdominal sternum," here of "basihyal." The basihyal has, however, coalesced with the thyrohyals to form a broad cartilaginous plate, the anterior border rising like a valve to close the fauces, and the

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* "Geol. Trans.," 1821, p. 565.

† "Bridgewater Treatise," 1836, vol. i., p. 176.

posterior angles extending beyond and sustaining the thyroid and other parts of the larynx. The long bony "ceratohyal" and the commonly cartilaginous "epihyal" are suspended by the ligamentous "stylohyal" to the paroccipital process; the whole arch having, like the mandibular one, retrograded from the connection it presents in fishes.

This retrogradation is still more considerable in the succeeding hæmal arch. In comparing the occipital segment of the crocodile's skeleton with that of the fish, the chief modification that distinguishes that segment in the crocodile is the apparent absence of its hæmal arch. We recognise, however, the special homologues of the constituents of that arch of the fish's skeleton in the bones 51 and 52 of the crocodile's skeleton (Fig. 18); but the upper or suprascapular piece, 50, retains, in connection with the loss of its proximal or cranial articulations, its cartilaginous state; the scapula, 51, is ossified, as is likewise the coracoid, 52, the lower end of which is separated from its fellow by the interposition of a median, symmetrical, partially-ossified piece called "episternum." The power of recognising the special homologies of 50, 51, and 52 in the crocodile, with the similarly-numbered constituents of the same arch in fishes—though masked, not only by modifications of form and proportion, but even of very substance, as in the case of 50—depends upon the circumstance of these bones constituting the same essential element of the archetypal skeleton, viz., the fourth hæmal arch, numbered *pl*, 52, in Fig. 7: for although in the present instance there is superadded, to the adaptive modifications above cited, the rarer one of altered connections, Cuvier does not hesitate to give the same names, "suprascapulaire" to 50, and "scapulaire" to 51, in both fish and crocodile; but he did not perceive or admit that the narrower relations of special homology were a result of, and necessarily included in, the wider law of general homology. According to the latter law, we discern in 50 and 51 a compound "pleurapophysis," in 52 a "hæmapophysis," and in *hs*, the "hæmal spine," completing the hæmal arch.

The scapulo-coracoid arch, both elements, 51, 52, of which retain the form of strong and thick vertebral and sternal ribs in the crocodile, is applied in the skeleton of that animal over the anterior thoracic hæmal arches. Viewed as a more robust hæmal arch, it is obviously out of place in reference to the rest of its vertebral segment. If we seek to determine that segment by the mode in which we restore to their centrums the less displaced neural arches of the antecedent vertebræ of the cranium or in the sacrum of the bird,* we proceed to examine the vertebræ before and behind the displaced arch, with the view to discover the one which needs it, in order to be made typically complete. Finding no centrum and neural arch without its pleurapophyses from the scapula to the pelvis, we give up our search in that direction; and in the opposite direction we find no vertebra without its ribs, until we reach the occiput; there we have centrum and neural arch, with coalesced parapophyses, but without the hæmal arch, which arch can only be supplied by a restoration of the bones 50-52 to the place which they naturally occupy in the skeleton of the fish. And since anatomists are generally agreed to regard the bones 50-52 in the crocodile (Fig. 18) as specially homologous with those so numbered in the fish (Fig. 9), we must conclude that they are likewise homologous in a higher sense; that in the fish the scapula-coracoid arch is in its natural or typical position, whereas in the crocodile it has been displaced for a special purpose. Thus, agreeably with a general principle, we perceive that, as the lower

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* See "On the Archetype and Homologies of the Vertebrate Skeleton," pp. 117 and 159.

vertebrate animal illustrates the closer adhesion to the archetype by the natural articulation of the scapulo-coracoid arch to the occiput, so the higher vertebrate manifests the superior influence of the antagonizing power of adaptive modification by the removal of that arch from its proper segment.

The anthropotomist, by his mode of counting and defining the dorsal vertebræ and ribs, admits, unconsciously perhaps, the important principle in general homology which is here exemplified; and which, pursued to its legitimate consequences, and further applied, demonstrates that the scapula is the modified rib of that centrum and neural arch, which he calls the "occipital bone;" and that the change of place which chiefly masks that relation (for a very elementary acquaintance with comparative anatomy shows how little mere form and proportion affect the homological characters of bones), differs only in extent, and not in kind, from the modification which makes a minor amount of comparative observation requisite, in order to determine the relation of the shifted dorsal rib to its proper centrum in the human skeleton.

With reference, therefore, to the occipital vertebra of the crocodile, if the comparatively well-developed and permanently-distinct ribs of all the cervical vertebræ prove the scapular arch to belong to none of those segments, and if that hæmal arch be required to complete the occipital segment, which it actually does complete in fishes, then the same conclusion must apply to the same arch in other animals, up to man himself.

The anterior locomotive extremity is the diverging appendage of the arch, under one of its numerous modes and grades of development. The proximal element of this appendage, or that nearest the arch, is called the "humerus," 53 (Fig. 18). The second segment of the limb consists of two bones; the larger one, 54, is called the "ulna:" it articulates with the outer condyle of the humerus by an oval facet, the thick convex border of which swells a little out behind, and forms a kind of rudimental "olecranon;" the distal end is much less than the proximal one, and is most produced at the radial side.

The radius, 55, has an oval head; its shaft is cylindrical; its distal end oblong and subcompressed.

The small bones, 56, which intervene between these and the row of five longer bones, are called "carpals;" they are four in number in the crocodilia. One seems to be a continuation of the radius, another of the ulna; these two are the principal carpals; they are compressed in the middle, and expanded at their two extremities: that on the radial side of the wrist is the largest. A third small ossicle projects slightly backwards from the proximal end of the ulnar metacarpal; it answers to the bone called "pisiforme" in the human wrist. The fourth ossicle is interposed between the ulnar carpal and the metacarpals of the three ulnar digits.

These five terminal-jointed rays of the appendage are counted from the radial to the ulnar side, and have received special names; the first is called "pollex," the second "index," the third "medius," the fourth "annularis," and the fifth "minimus." The first joint of each digit is called "metacarpal;" the others are termed "phalanx." In the crocodilia the pollex has two phalanges, the index three, the medius four, the annularis four, and the minimus three. The terminal phalanges, which are modified to support claws, are called "ungual" phalanges.

As the above-described bones of the scapular extremity are developments of the appendage of the scapular arch, which is the hæmal arch of the occipital vertebra, it follows, that, like the branchiostegal rays and opercular bones in fishes, they are essentially bones of the head. But the enumeration of the bones of the crocodile's skull is not completed by these; there is a bone anterior to the orbit, which is perforated at its orbital border by the duct of the lacrymal gland, whence it is termed the "lacrymal bone," and its facial part extends forwards between the bones marked 14, 15, 21, and 26. In many crocodilia there is a bone at the upper border of the orbit, which extends into the substance of the upper eyelid; it is called "superorbital." In the crocodilus palpebrosus there are two of these ossicles.

Both the lacrymal and superorbital bones answer to a series of bones found commonly in fishes, and called "suborbitals" and "superorbitals." The lacrymal is the most anterior of the suborbital series, and is the largest in fishes; it is also the most constant in the vertebrate series, and is grooved or perforated by a mucous duct. These ossicles appertain to the dermal or muco-dermal system or "exoskeleton," not to the vertebral system or "endoskeleton."

There remains, to complete this sketch of the osteology of the crocodile, a brief notice of the bones composing the diverging appendage of the pelvic arch: these being a repetition of the same element as the appendage of the scapular arch, modified and developed for a similar office, manifest a very close resemblance to it. The first bone, called the "femur," is longer than the humerus, and, like it, presents an enlargement of both extremities, with a double curvature of the intervening shaft, but the directions are the reverse of those of the humerus, as may be seen in Fig. 18, where the upper or proximal half of the femur is concave, and the distal half convex, anteriorly. The head of the femur is compressed from side to side, not from before backwards as in the humerus; a pyramidal protuberance from the inner surface of its upper fourth represents a "trochanter;" the distal end is expanded transversely, and divided at its back part into two condyles. The next segment of the hind-limb or "leg," includes, like the corresponding segment of the fore-limb called "fore-arm," two bones. The largest of these is the "tibia," 66, and answers to the radius. It presents a large, triangular head to femur; it terminates below by an oblique crescent with a convex surface. The "fibula" is much compressed above; its shaft is slender and cylindrical, its lower end is enlarged and triangular. The group of small bones which succeed those of the leg are the tarsals; they are four in number, and have each a special name. The "astragalus" articulates with the tibia, and supports the first and part of the second toe. The calcaneum intervenes between the fibula and the ossicle supporting the two outer toes; it has a short but strong posterior tuberosity. The ossicle referred to represents the bone called "cuboid" in the human tarsus. A smaller ossicle, wedged between the astragalus and the metatarsals of the second and third toes is the "ectocuneiform."

Four toes only are normally developed in the hind-foot of the crocodilia; the fifth is represented by a stunted rudiment of its metatarsal, which is articulated to the cuboid and to the base of the fourth metatarsal. The four normal metatarsals are much longer than the corresponding metacarpals. That of the first or innermost toe is the shortest and strongest; it supports two phalanges. The other three metatarsals are of nearly equal length, but progressively diminish in thickness from the second to the fourth. The second metatarsal supports three phalanges; the third four; and the fourth also has four phalanges, but does not support a claw. The fifth digit is represented by a rudiment of its metatarsal in the form of a flattened triangular plate of bone, attached to the outer side of the cuboid, and slightly curved at its pointed and prominent end.

The forms and proportions of the entire skeleton of the crocodile are adapted to the necessities of an amphibious animal, but minister to much more rapid and energetic movements in water than on land. The short limbs preclude the possibility of very quick course along shore; and the overlapping of the ribs of the neck, whilst enabling the head the better to cleave the water during the acts of diving or swimming, makes the bending of that part from side to side an act of difficulty and time; this, it is said, may avail any one pursued by a crocodile on dry land to escape by turning out of the straight course. But the crocodile usually seizes his prey by stratagem or concealment when in or close to the water; and it is there that he shows himself master of his position, and chiefly by the powerful strokes of his long, large, vertically-flattened tail.

Osteology of Chelonian Reptiles—Tortoises and Turtles.—Those animals to which, in the manifold modifications of the organic framework, a portable dwelling or place of refuge has been given, in compensation for inferior powers of locomotion or other means of escape or defence, have always attracted especial attention; and of them the most remarkable, both for the complex construction of their abode as well as for their comparatively high organization, are the reptiles of the chelonian order. The expanded thoracic-abdominal case, into which, in most chelonians, the head, the tail, and the four extremities can be withdrawn, and in some of the species be there shut up by moveable doors closely fitting both the anterior and posterior apertures —as, *e.g.*, in the box-tortoises (*cinosternon*, *cistudo*)—has been the subject of many and excellent investigations; and not the least interesting result has been the discovery that this seemingly special and anomalous superaddition to the ordinary vertebrate structure is due, in a great degree, to the modification of form and size, and, in a less degree, to a change of relative position, of ordinary elements of the vertebrate skeleton.

The natural dwelling-chamber of the chelonia consists chiefly, and in the marine species (*chelone*) and mud-turtles (*trionyx*) solely, of the floor and the roof: side-walls of variable extent are added in the fresh-water species (*emydians*) and land-tortoises (*testudinians*). The whole consists chiefly of osseous "plates" with superincumbent horny plates or "scutes," except in the soft or mud-tortoises (*trionyx* and *sphargis*), in which these latter are wanting.

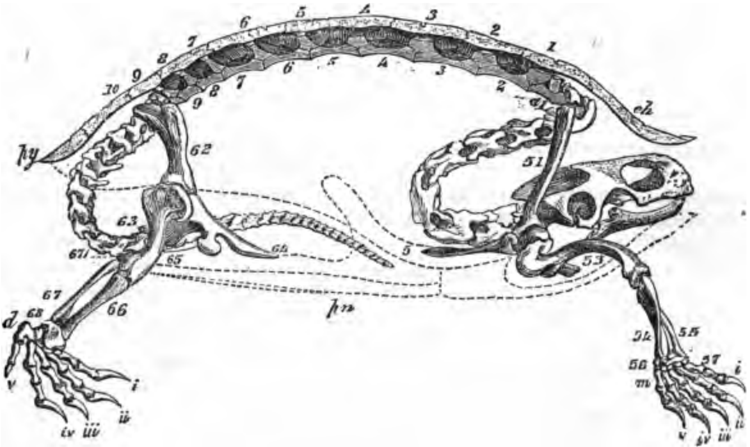
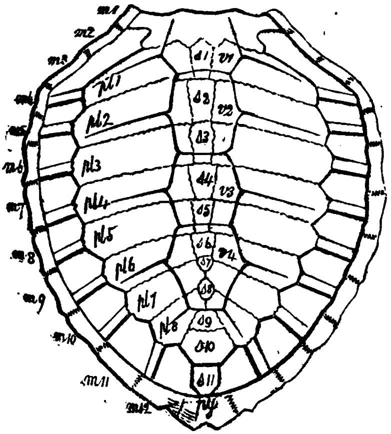


Fig. 20.—SKELETON OF THE EUROPEAN TORTOISE.

Fig. 20 shows the manner in which the head and tail can be retracted within the thoracic-abdominal box: the four limbs are figured as extended in the act of walking, to show their structure. The only moveable vertebræ are those of the neck and tail, and the former enjoy a great degree of flexibility. The vertebræ answering to the dorsal, lumbar, and sacral series are firmly fixed together; but the dorsal ones, 1 to 8, are chiefly concerned in the formation of the osseous dwelling-chamber. The composition of this will be first described as it exists in the turtle (*chelone*), the species called "loggerhead" being here selected for its illustration.

In the marine species of the chelonian order, of which this may be regarded as the type, the ossification of the carapace and plastron is less extensive, and the whole skeleton is lighter, than in the box-tortoise (Fig. 20), or any of those species that live on dry land. The head is proportionally larger,—a character common to aquatic animals; and, being incapable of retraction within the carapace, ossification extends in the direction of the fascia covering the temporal muscles, and forms a second bony covering of the cranial cavity: this accessory defence is not due to the intercalation of any new bones, but to exogenous growths from the frontals, 11, postfrontals, 12, parietals, 7, and mastoids, 8.

Fig. 21.

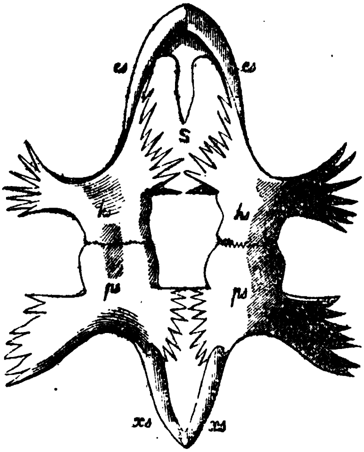


CARAPACE OF TURTLE (*Chelone imbricata*).

The carapace (Fig. 21) is composed of a series of median and symmetrical pieces *ch*, *s* 1 to *s* 11, and of two series of unsymmetrical pieces on each side. The median pieces have been regarded as lateral expansions of the summits of the neural spines; the medio-lateral pieces as similar developments of the ribs; and the marginal pieces as the homologues of the sternal ribs. But the development of the carapace shows that ossification begins independently in a fibro-cartilaginous matrix of the corium in the first, *ch*, and some of the last, *s* 9 to *s* 11, median plates, and extends from the summits of the neural spines into only eight of the intervening plates, *s* 1 to *s* 8: ossification also extends into the contiguous lateral plates, *pl* 1 to *pl* 8, in some chelonia, not from the corresponding part of the subjacent ribs, but from points alternately nearer and farther from their heads, showing that such extension of ossification into the corium is not a development of the tubercle of the rib, as has been supposed. Ossification commences independently in the corium in all the marginal plates, *m* 1 to *py*, which never coalesce with the bones uniting the sternum with the vertebral ribs, and which are often more numerous, and sometimes less numerous than those ribs, and in a few species are wanting. Whence it is to be inferred that the expanded bones of the carapace, which are supported and impressed by the thick epidermal scutes called "tortoise-shell," are dermal ossifications, homologous with those which support the nuchal and dorsal epidermal scutes in the crocodile. Most of the pieces of the carapace being directly continuous or connate with the obvious elements of the vertebræ, which have been supposed exclusively to form them by their unusual expansion, the median ones, *s* 1 to *s* 11, have been called "neural plates," and the medio-lateral pieces, *pl* 1 to *pl* 8, "costal plates;" but the external lateral pieces, *m* 1 to *m* 12, have retained the name of "marginal plates." The first or anterior of the median plates (*ch*, "nuchal plate") is remarkable for its great breadth in the turtles, and usually sends down a ridge from the middle line of its under surface, which articulates more or less directly with the summit of the neural arch of the first dorsal vertebra; the second neural plate is much narrower, and is connate with the summit of the neural spine of the second dorsal vertebra: the seven succeeding neural plates have the same relations with the succeeding neural spines: the rest are independent dermal bones. The costal plates of the carapace are superadditions to eight pairs of the pleurapophyses or vertebral portions of the second to the ninth ribs inclusive. The slender or proper portions of these ribs project freely for some distance beyond the connate dermal portions, along the under surface of which the rib may be traced, of its ordinary breadth to near the head, which liberates itself from the costal plate to articulate to the interspace of the two contiguous vertebræ, to the posterior of which such rib properly belongs.

The plastron, or floor of the bony house, consists in the genus *Chelone*, as in the rest of the order, of nine pieces,—one median and symmetrical, and the rest in pairs. With regard to the homology of these bones, three explanations may be given: one in conformity with the structure of the thoracic-abdominal cage in the crocodile; the other based upon the analogy of that part in the bird; and the third agreeably with the phenomena of development. According to the first, the median piece of the plastron, called "ento-sternal," S, answers to the sternum of the crocodile, or "sternum proper," and the four pairs of plastron-pieces, *es*, *hs*, *ps*, *xs*, answer to the "hœmapophyses" forming the so-called sternal and abdominal ribs of the crocodile. Most comparative anatomists have, however, adopted the views of Geoffroy St. Hilaire, who was guided in his determination of the pieces of the plastron by the analogy of the skeleton of the bird; according to which all the parts of the plastron are referred to a complex and greatly developed sternum, and the marginal plates are viewed as sternal ribs (hæmapophyses). The third ground of determination refers the parts of the plastron, like those of the carapace, to a combination of parts of the endoskeleton with those of the exoskeleton.

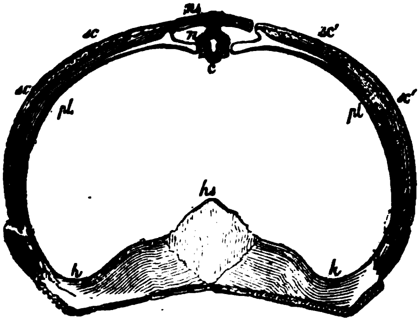
Fig. 22.



PLASTRON OF CHELONE CAOUANNA.

In Fig. 21, the marginal plates, *m* 1 to *m* 12, are twenty-four in number, or twenty-six if the first (nuchal, *ch*) and last (pygal, *py*) vertebral plates be included. Omitting these in the enumeration, three marginal pieces intervene on each side at the angles between the first median plate and the point of the first costal plate formed by the end of the second dorsal rib, which point enters a depression in the fourth marginal piece, *m* 4; the fifth, sixth, seventh, eighth, ninth, and tenth marginal plates are similarly articulated by gomphosis to the six succeeding ribs; the eleventh marginal plate has no corresponding rib; the twelfth is articulated with the point of the ninth dorsal rib supporting the eighth costal plate.

Fig. 23.



SEGMENT OF CARAPACE AND PLASTRON.

The want of concordance with the vertebral ribs, or "pleurapophyses," arising from the increased number of the marginal pieces, favours the idea of their being dermal ossifications, such peripheral elements being more subject to vegetative division and multiplication than the hæmapophyses: the absence of the marginal pieces in the trionyx gives additional support to the same view. The median piece, S, is here regarded as a hæmal spine: it is called "entosternum." The parial pieces of the plastron are the "hæmapophyses" connate with expanded dermal ossifications, and have received the following special names: *es*, "episternal;" "*hs*, "hyosternal;" *ps*, "hyposternal;" *xs*, "xiphisternal."

In some extinct chelonia the number of these lateral elements of the plastron is increased by an intercalated pair which I have called "mesosternals." In the figure of the segment, as modified to form the carapace and plastron (Cut 23), the nature of the bones is indicated by the letters according to the explanation given of the archetype vertebræ (Fig. 5, p. 169), the dermal superadditions being marked *sc.*

In the figure of the skeleton of the box-tortoise (Fig. 20) a section of the carapace and plastron has been removed from the right side to expose the dorsal and sacral vertebræ, and the disposition of the scapular and pelvic arches. The eight cervical vertebræ are free, moveable, and ribless; the fourth of these vertebræ has a much elongated centrum, which is convex at both ends; the eighth is short and broad, with the anterior surface of the body divided into two transversely elongated convexities, and the posterior part of the body forming a single convex surface divided into two lateral facets; the under part of the centrum is carinate. The neural arch, which is anchylosed to this centrum, is short, broad, obtuse, and overarched by the broad expanded nuchal plate, *ch.* The first dorsal vertebra, *d* 1, is also short and broad, with two short and thick pleurapophyses, articulated by one end to the expanded anterior part of the centrum, and united by suture at the other end to the succeeding pair of ribs. The head of each rib of the second pair is supported upon a strong trihedral neck, and articulated to the interspace of the first and second dorsal vertebræ: it is connate, at the part corresponding to the tubercle, with the first broad costal plate, which articulates by suture to the lateral margin of the first neural plate, and to portions of the nuchal and third neural plates: the connate rib, which is almost lost in the substance of the costal plate, is continued with it to the anterior and outer part of the carapace, where it resumes its subcylindrical form, and articulates with the second and third marginal pieces of the carapace. The neural arch of the second dorsal vertebra is shifted forwards to the interspace between its own centrum and that of the first dorsal vertebra. A similar disposition of the neural arch and spine and of the ribs prevails in the third to the ninth dorsal vertebræ inclusive. The corresponding seven neural plates are connate with the spines of those vertebræ, and form the major part of the median pieces of the carapace; the corresponding costal plates, anchylosed to the ribs, form the medio-lateral pieces; the ninth, tenth, and pygal plates, with the marginal plates of the carapace, do not coalesce with any parts of the endo-skeleton. The bony floor of the great abdominal box, or "plastron," is formed by the hæmapophyses and sternum connate with dermal osseous plates, forming, as in the turtle, nine pieces, one median and symmetrical, answering to the proper sternum, and eight in pairs: but they are more ossified, and the hyo- and hypo-sternals unite suturally with the fourth, fifth, and sixth marginal plates, forming the side-walls of the bony chamber. The junction between the hyo- and hypo-sternals admits of some yielding movement. The iliac bones, 62, abut against the pleurapophyses of the tenth, eleventh, and twelfth vertebræ, counting from the first dorsal vertebra. These three vertebræ form the sacrum: their pleurapophyses are unanchylosed, converge, and unite at their distal extremities to form the articular surface for the ilium. Beyond these the vertebræ, thirty-five in number, are free, with short, straight, and thick pleurapophyses, articulated to the sides of the anterior expanded portions of the centrums. They diminish to mere tubercles in the first caudal vertebra, and disappear in the remainder. The neural arches of the caudal vertebræ are flat above, and without spines. The strong columnar scapula, 51, is attached by ligament to the first costal plate, and, retaining its primitive rib-like form, it descends almost vertically to the shoulder-joint, of which it forms, in common with the coracoid, 52, the glenoid cavity. A strong subcylindrical process or continuation of the scapula, representing the acromion, bends inwards to meet its fellow at the middle line. The coracoid continues distinct from the scapula, expands, and becomes flattened at its median extremity, which does not meet its fellow or articulate with the sternum. The iliac bones, 62, are vertical and columnar, like the scapula, but are shorter and more compressed: they articulate, but do not coalesce, with the pubis, 64, and ischium, 63. The acetabulum is formed by contiguous parts of all the three bones. The pubis arches inwards, and expands to join its fellow at the median symphisis and the ischium posteriorly. It sends outwards and downwards a long thick obtuse process from its anterior margin. The ischia, in like manner, expand where they unite together to prolong the symphysis backwards.

In the skull the parietal crista is continued into the occipital one without being extended over the temporal fossæ, as in the turtle; the fascia covering the muscular masses in these fossæ undergoing no ossification. The bony hoop for the membrana tympani is incomplete behind, and the columelliform stapes passes through a notch instead of a foramen to attain the tympanic membrane. The mastoid is excavated to form a tympanic air-cell. In the Australian long-necked terrapene (*hydraspis longicollis*) the head is much depressed, the mastoids are excavated by large tympanic cells, and prolonged backwards: the frontal is produced forwards as far as the anterior nostril, where it terminates in a point between the two nasals, which are here distinct from the prefrontals. The margins of the upper and lower jaws are trenchant: the hypapophysis of the atlas has the form of a diminutive wedge-bone, forming as usual the lower part of the articular cup for the occipital condyle: the rest of the body of the atlas, or "odontoid," has coalesced with its proper neural arch, which developes two transverse and two long posterior oblique processes, as in the chelys.

In the true or land tortoises the temporal depressions are exposed, as in the box-tortoises and fresh-water terrapenes: the head is proportionally small, and can be withdrawn beneath the protective roof of the carapace. The skull is rounder and less depressed than in the terrapenes: the frontals enter into the formation of the orbital border. The tympanic hoop is notched behind, but the columelliform stapes passes through a small foramen. The palatine processes of the maxillaries are on a plane much below that of the continuation of the basis cranii, formed by the vomer and palatines. In most of the chelonia the nasal bone is connate with the prefrontal; and, in all, the tympanic pedicle is firmly wedged between the broad appendage of the maxillary arch, formed by the malar, 26, and squamosal, 27, in front, and the mastoid, 8, behind. The broad-headed terrapene (*podocnemys expansa*) differs from other fresh-water tortoises, and approaches the marine tortoises (turtles), by the vaulted bony roof arching over the temporal depressions. This roof is chiefly formed by the parietals, but differs from that in the turtles in being completed laterally by a larger proportion of the squamosal than of the postfrontal, which does not exceed its relative size in other terrapenes. The present species further differs from the marine turtles in the non-ossification of the vomer and the consequent absence of a septum in the posterior nostrils; in the greater breadth of the pterygoids, which send out a compressed rounded process into the temporal depressions: the orbits also are much smaller, and are bounded behind by orbital processes of the postfrontal and malar bones: the mastoids and paroccipitals are more produced backwards, and the entire skull is more depressed than in the turtles.

The ordinary position of the scapular extremity is a state of extreme pronation, as shown in Fig. 20, with the olecranon, or top of 54, thrown forwards and outwards, and the radial side of the hand, or thumb, *i*, directed to the ground. The humerus, 53, is strongly bent in a sigmoid form, with the anconal surface convex and directed upwards and outwards: the two tuberosities at the proximal end are much developed and bent towards the palmar aspect, bounding a deep and wide groove: that which answers to the external tuberosity is the smallest, and by the rotation of the humerus it becomes the most internal in position. The proximal row of the carpus consists of four bones—viz., a large scaphoides, a small lunare, wedged into the interspace of the radius and ulna, a large cuneiforme, and a small pisiforme. The second row consists of five distinct bones, corresponding with the five digits; those supporting the fourth and fifth answering to the os unciforme, the remaining three to the trapezium, trapezoides, and magnum. The first and fifth of the digits have each one metacarpal and two phalanges; the rest, *ii*, *iii*, *iv*, have each a metacarpal and three phalanges. A sesamoid bone is placed beneath the metacarpo-phalangeal joint of the three middle digits.

In the pelvic extremity, the femur, 65, is sigmoidally bent, but in a less degree than the humerus, and is a shorter bone. The patella is ligamentous: the synovial joint between it and the femur is distinct from the proper capsule of the knee-joint; the fibula, 66, is longer and more slender than the tibia, 66; a small "fabella" is articulated to its upper end. The proximal row of the tarsus consists of two bones, astragalus and calcaneum, which sometimes become confluent. The distal row consists of five bones, four of which support the four normal toes, and the fifth, a rudiment of the fifth toe without a claw: the fourth and fifth of the second row of tarsals answer to the os cuboides of higher animals; the other three bones to the three ossa cuneiformia. The astragalar part of the single proximal bone would seem to include the scaphoid as well as the calcaneum.

In the marine chelonia the digits of both limbs are elongated, flattened, and united by a web; the hands and feet having the form of fins.

In all the chelonia the long bones of the limbs are solid, without medullary cavities.

The Skeleton of Birds.—From the massive frame of the cold-blooded, heavy, and proverbially slow tortoise, to the light, hot-blooded, flying bird, the transition seems to be abrupt, and the discrepancy between creatures so differently endowed extreme; nevertheless, at the confines of the feathered class, we find some aquatic species, such as the penguin, incapable of flight, having the wings modified to act as fins, and much resembling those of the turtle; with the bones solid, and the feathers resembling scales. All birds, like tortoises, lay eggs, are devoid of teeth, and have their jaws sheathed with horn, and forming a bill or beak. Most birds, however, enjoy the faculty of flight.

If the student of comparative osteology will procure the skull of a rook, a hawk, a swan, or a sea-gull, and vertically bisect it, he will have a ready instance illustrative of some of the characteristics of the osteology of the feathered class. Such a section will show the ivory-like whiteness and compactness of the osseous tissue, and the loose open cancellous structure of the bones. He will see that air is admitted into these cancelli partly from the nasal passages, and partly from the tympanic cavity which receives it from the eustachian tube; from the latter source, the proper bones of the cranium receive their air. Some of the characteristic features in the composition of the skull of birds may also be noticed: as, for example, the obliteration of all the ordinary sutures of the cranium, except those which unite the tympanic bone, 28, to the mastoid, 8; and that which unites the pterygoid, 23, to the basisphenoid, 5; which sutures are speedily obliterated in the human subject. The premaxillary is confluent with the nasal and with the maxillary; the nasal being confluent with the frontal and the maxillary with the jugal. The jugal and squamosal are also confluent, and form a long zygomatic style in all birds, connected at the hinder extremity by a moveable glenoid joint to the outer and lower part of the tympanic. The pterygoid articulates, in like manner, with the inner and lower part of the tympanic, the movements of which are thus communicated to the upper mandible, so far as the junction of the nasal with the frontal admits of such independent motion. The upper jaw, or mandible, which includes the vomer and nasals with the maxillary arch and appendages, is moveable in a bird through the junction of the nasals and nasal branch of the premaxillary with the frontal, by means of a moveable articulation, or by elastic plates.

If the student will next separate one of the vertebræ of the trunk from the rest, and cut out that portion of the long and broad breast-bone to which its pair of ribs are attached, he will have a segment of the skeleton, answering to that figured in Fig. 5, p. 169.

The cut surfaces will demonstrate the light cellulosity of the divided bones. The following letters indicate the elements of such modified vertebræ of the thorax: *y*, centrum, with its hypapophysis; *p*, parapophysis; *d*, diapophysis; *n*, neural arch and rudimental spine; *pl*, pleurapophysis; *h*, hæmapophysis; *hs*, hæmal spine. The tendency of individual elements and bones to coalesce in birds has already been illustrated in the cranium; it is shown, in most birds of flight, not only by the confluence of the centrum with the neural arch, but by that of several consecutive centrums and arches into a single bone, in the ample chest. In like manner the hæmal spines, which continue distinct in many vertebrata, have here coalesced into a single bone, which articulates on each side with the hæmapophyses of several vertebræ. These coalesced spines are also much developed in breadth, and send down, from the middle of their under surface, a longitudinal crest or keel. This modification relates to the extension of the surface for the origin of the great muscles of flight, and renders the "sternum," as the coalesced series of hæmal spines is called, one of the most characteristic parts of the skeleton of the bird. Ossification extends from the neural arches into the tendons of the vertebral muscles, and such bone-tendons, both here and in other parts of the body, as the legs, are also characteristic of birds. The scapula (Fig. 24), 51, is long and slender, as in the chelonia, but is more compressed and sabre-shaped. The coracoid, 52, as a general rule, is a distinct bone, moveably articulated to the scapula at one end and to the sternum at the other. Its broad sternal end here articulates by a kind of gomphosis with a deep groove on the fore part of the sternum. The clavicle (*ib.*), 58,

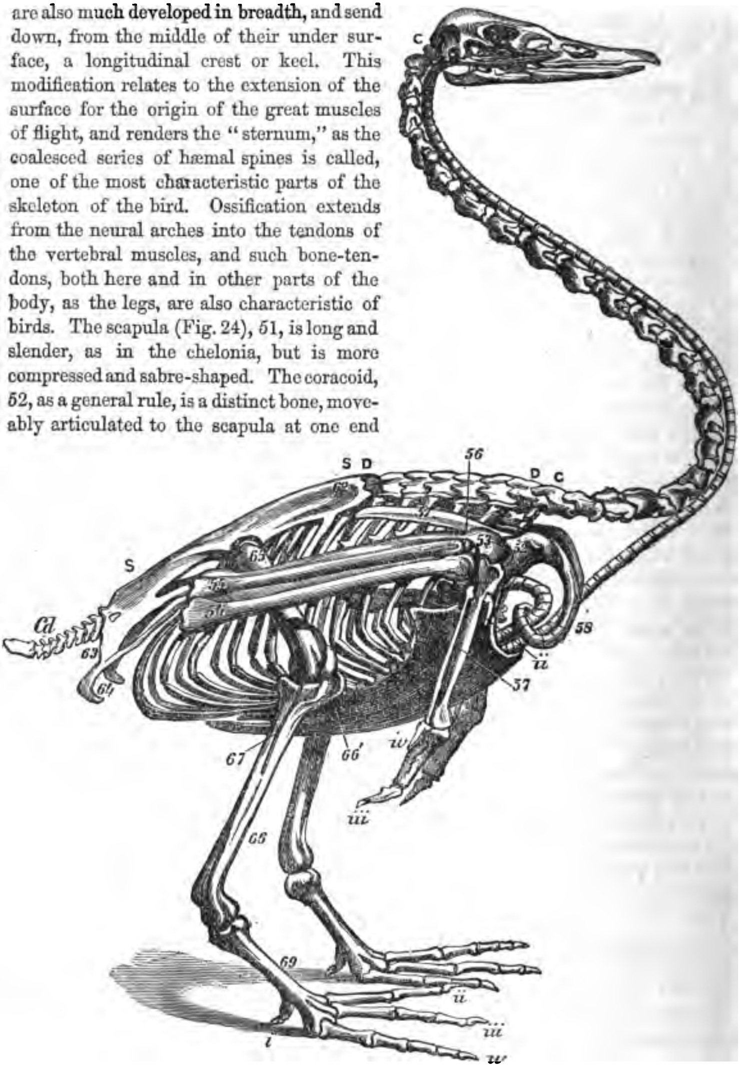


Fig. 24.—SKELETON OF THE SWAN (*Cygnus ferus*).

articulates with the coracoid above, but is confluent with its fellow and with the keel of the sternum below. The iliac bones, 62, are remarkable for their length, and for the number of the vertebræ, or the great extent of the confluent spinal column, to which they are anchylosed. They reach in the swan, and in most other birds, from the tail forwards to the vertebræ with moveable ribs. Thus the artificial characters of a "lumbar vertebra" are wanting. The pubis and ischium on each side have coalesced with the ilium to form the lower boundary of the widely-perforated acetabulum. The pubis is long and slender, joins the ischium of its own side near its lower extremity, but does not join its fellow; thus the foramen ovale is defined, but there is no symphysis pubis: the absence of this symphysis facilitates the expulsion of the large ovum with its unyielding calcareous shell. The ischium coalesces posteriorly with the ilium, and converts the ischiadic notch into a foramen. The caudal vertebræ, *Cd*, are few in number, with broad transverse processes formed by confluent pleurapophyses, the limits of which may still be traced. A hæmapophysis is articulated to the lower interspace, between the fourth and fifth caudal, and is anchylosed to the sixth. The humerus of some of the larger birds of flight—*e. g.*, the pelican or adjutant crane—is remarkable for its lightness, as compared with its bulk and seeming solidity; it is, in fact, a mere shell of compact osseous tissue. The orifice admitting air to its large cavity is beneath the great tuberosity at the proximal end.

The keel is excavated, not only for the reception of an air-cell, but likewise for a fold of the windpipe, which fold expands with age, and lies horizontally in the substance of the back part of the sternum. Small pneumatic foramina are situated at the anterior and inner surface of the bone, and perforate the articular surfaces for the sternal ribs.

In the skeleton of the wild swan (*Cygnus ferus*) (Fig. 24), here selected as an illustration of the ornithic modification of the vertebrate type, there are not fewer than twenty-eight vertebræ, C S D, between the skull and the sacrum, the last six of which, D D, support moveable ribs: of these the first and second pairs are free; the next four are articulated to the sternum by bony hæmapophyses; the last five pairs of ribs are attached to the sacrum and also to the sternum; but the tenth, or last rib on the left side, is very rudimentary, being only about one inch in length. There are eight caudal vertebræ, *Cd*. The trachea or windpipe penetrates the sternum, and bends and winds in the interior of the bone before returning to enter the chest. The apex of the furculum, 58, bends upwards, and forms a hoop over the windpipe as it enters into the keel of the breast-bone. The furculum, sometimes called "merrythought," consists of the two clavicles confluent at their lower free ends. If a portion of the one side of the sternum be removed, the tortuous trachea which it incloses will be exposed. To the great length and peculiar course of the windpipe in this species is to be attributed its remarkably loud and harsh voice; whence the name hooper, or whistling swan, has been derived; and is applied in contradistinction to the domestic or mute swan, in which, as in most other birds, the trachea proceeds at once to the lungs, without entering the sternum. In the female of the wild species, the course of the trachea is much more limited than in the male, seldom penetrating the sternum to a greater extent than from three to four inches.

The breadth of the sternum, and the strong ridge or keel that descends from the mid-line of its under surface, relate to the increased extent of surface required for the attachment of the "pectoral" muscles, which are the active organs of flight. In the land-birds devoid of the power of flight, such as the ostrich and apteryx, the keel is wanting and the sternum is short. Its various proportions, processes, notches, and perforations render it a very characteristic bone in birds.

In no order, founded upon modifications of the feet, is the sternum more diversified in character than in the palmipedes or web-footed order; for in none are the powers of flight enjoyed in such different degrees, or exercised in such various ways, from the frigate-bird down to the penguins, where the power of flight is abrogated, and the rudimental wings used as fins.

In the goose and duck tribes, as well as the swans (*anseres*, Linn.), the sternum is long and broad, and presents two moderately wide and deep hind notches; the costal processes are usually subquadrate; the coracoid grooves are continued into one another at the median line; the costal tract forms about half of the lateral margin in the ducks and geese, and two-thirds or more in the swans; the interpectoral ridge extends from the prominent part of the coracoid margin backwards, nearly parallel to the lateral margin, to the inner side of the lateral grooves; the back part of the sternum between the grooves is quadrate, with the angles slightly produced in most; there is a short manubrial process below the coracoid groove. The form of the sternum, its long keel, and the backward production of the long and slender ribs, give a boat-like figure to the trunk of these swimming-birds which is well adapted to their favourite medium and mode of locomotion. The bones of the wing or anterior extremity do not present that extraordinary development which might be expected from the powers of the member of which they form the basis. The great expanse of the wing is gained at the expense of the epidermoid system (quills and feathers, like hairs and scales, are thickened epiderm), and is not exclusively produced by folds of the skin requiring elongated bones to support them, as in the flying-fish, flying-lizards, and bats. The wing-bones of birds are, however, both in their forms and modes of articulation, highly characteristic of the powers and applications of the muscular apparatus requisite for the due actions of flight. The bones of the shoulder consist on each side of a scapula, 51, a coracoid, 52, and a clavicle, 58, the clavicles being, as a general rule in birds, confluent at their median ends, and so forming a single bone called "furculum" or "os furcatorium;" this further modification of the hæmal arch in birds, repeating that of the pubis and lower jaw in some other animals, having occasioned an additional specific term in ornithotomy. The scapula, 51, is a long, narrow, flat sabre-shaped plate, expanded at the humeral end, where it forms externally part of the joint for the arm-bone called "glenoid cavity," and extended backwards nearly parallel with the vertebræ, as far as the ilium, 62, in the swan, and reaching to the last rib in the swift; but it is much shorter in the birds incapable of flight. The coracoid is the strongest of the bones of the scapular arch: it forms the anterior half of the glenoid cavity, extends above this part to abut upon the furculum, and is continued downwards below the joint, expanding, to be fixed in the transverse groove at the fore part of the sternum; it thus forms the chief support of the wing, and the main point of resistance during its downward stroke. In the hawks and other birds of prey, and in the crows and most passerine birds, a small bone (os humero-capsulare) extends between the scapula and coracoid along the upper part of the glenoid cavity; this is absent in the swan and other swimmers, as well as in the gallinaceous and wading birds. The humerus, 53, is usually a long and slender bone, but is not always developed in length in proportion to the powers of flight; for, although it is shortest in the struthious birds and penguins, it is also very short, but much thicker and stronger in the swift and humming-birds. The head of the humerus is transversely oblong and convex; it is further enlarged by two lateral crests; of these the superior is the longest, and is bent outwards; the inferior is thickened and incurved, and beneath it is situated the orifice by which the air penetrates the cavity of the bone. The articular surface at the opposite or "distal" end is divided into two parts, one internal, for the ulna, of a hemispheric form, the other also convex, but more elongated and oblique, extending some way upon the anterior surface of the humerus. The extremity of a long bone of a limb which is next the trunk is called the "proximal" one; the extremity farthest from the trunk the "distal" one: they are not always "upper" and "lower." The ulna, 55, glides upon the inner hemispheric tubercle, upon the trochlear canal, and on the back part of the outer convexity. A ligament, extending from the outer part of the head of the radius to the outer part of the olecranon, above the posterior margin of the outer division of the articular surface of the ulna, plays upon the back part of the radial convexity of the humerus, and completes the cavity receiving it. The ulna is always stronger than the radius; but both are long, slender, and nearly straight bones, so articulated together as to admit of scarcely any rotation which adds to the resisting power of the wing in the action of flight. The upper part of the ulna, or "olecranon," is short. In the tendon attached to it a separate ossicle is developed in the swift, and two such bones in the penguin. The ulna is often impressed by the insertions of the great quill-feathers of the wing.

The bones of the hand are very long and narrow, with the exception of the two distinct or unanchylosed carpal bones; these are so wedged in between the antibrachium, 54, 55, and the metacarpus, 57, as to limit the motions of the hand to abduction and adduction, or those necessary for folding up and spreading out the wing. The hand is thus fixed in a state of pronation; all power of flexion, extension, and rotation is removed from the wrist joint; so that the wing strikes firmly, and with the full force of the depressed muscles, upon the resisting air. The part of the hand numbered 57 in Fig. 24 includes the metacarpal bones of the digits answering to the second, third, and fourth of the pentadactyle members, which are confluent at their proximal ends with each other, and with the "os magnum," one of the carpal bones, now forming the convex base of the middle metacarpal. This metacarpal and that answering to the "fourth" digit are of equal length, and are also confluent at their distal ends; but the middle or "third" metacarpal is much the strongest. That answering to the "second" digit, *ii*, is very short, and like a mere process from the third; it supports two short phalanges in the swan. The third metacarpal supports three phalanges, *iii*, the fourth a single phalanx, *iv*. All these are wrapped up in a sheath of integument, and are strongly bound together; so that the wing loses nothing of its power, whilst so much of the typical structure of the member is retained, that every bone can be referred to its corresponding bone in the most completely developed hand.

In ornithology the large quill-feathers that are attached to the ulnar side of the hand are termed "primariæ," or primary feathers; those that are attached to the fore-arm are the "secundariæ," or sécondaries, and "tectrices," or wing-coverts; those which lie over the humerus are called "scapulariæ," or scapularies; and those which are attached to the short outer digit, *ii*, erroneously called the "thumb," are the "spuriæ," or bastard feathers. The bones of the leg do not present the same number of segments as those of the wing, that corresponding with the carpus being wholly blended with the one that succeeds.

The pelvic bones offer this contrast with those of the shoulder, that they are always anchylosed on either side into one piece, "os innominatum" and not at the median line, whilst this is the only place where the elements of the scapular apparatus are united by bone. In the young bird the os innominatum is composed of three bones. The ilium, 62, is flattened, elongated, usually anchylosed to a very long sacrum: it forms the upper half of the joint for the thigh-bone, called "cotyloid cavity." The pubis, 64, is very long and slender: it does not meet its fellow at the middle line in any bird save the ostrich, but is directed backwards, with its free extremity bent downwards. The pelvis of the ostrich is so vast, that the pubic junction completing it does not impede the exit of the egg; in other birds the open pelvis facilitates the passage of that large and brittle generative product. The ischium, 63, is a simple elongated bone, extending from the cotyloid cavity backwards, parallel with the ilium; it sometimes coalesces, as in the swan, with both the ilium and pubis at its distal end.

The cotyloid cavity is incomplete behind, and is closed there by ligament. The femur, 65, is a short, cylindrical, almost straight bone; the head is a small hemisphere, presenting at its upper part a depression for the "round ligament." The single large "trochanter" generally rises above the articular eminence, and is continuous with the outer side of the shaft. The orifice for the admission of air is situated in the depression between the trochanter and head. The distal end presents two condyles, the inner one for the inner condyloid cavity of the tibia; the outer one for the outer cavity of the tibia and for the fibula; the outer condyle is produced into a semicircular ridge, which passes between the tibia and fibula: this ridge puts the outer elastic ligament on the stretch, when the fibula is passing over the condyle, and the fibula is pulled into a groove at the back of the condyle, with a jerk, when in extreme flexion; this spring-joint is well exemplified in both the swan and water-hen.

The proximal end of the tibia is divided into the two shallow condyloid cavities above noticed: two ridges are extended from its upper and anterior surface: the strongest of these is the "procnemial" ridge, and is slightly bent outwards: the shorter one on the outside of this is the "ectocnemial" ridge; they are usually united above by a transverse ridge, called "epicnemial" ridge; this is developed into a long process in the divers, grebes, and guillemots: a fibular ridge projects slightly from the upper third of the tibia for junction with the fibula. The distal end of the tibia forms a transverse pulley or trochlea, with the anterior borders produced. Above the fore part of the trochlea is a deep depression, and in many birds an osseous bridge extends across it.

The third segment of the leg, 69, is a compound bone, consisting originally of one proximal piece, short and broad, presenting two articular concavities to the two thick and round borders of the tibial trochlea, of three metatarsals which coalesce with each other and with the above tarsal piece, and of one or more bony processes which are ossified from the back part of the proximal piece, or from the proximal ends of the metatarsals, and which, from their relations to the extensor tendons, are called "calcaneal" processes. In most birds a small rudimental metatarsal, supporting the innermost toe or "hallux," *i*, is articulated by ligament with the innermost of the coalesced metatarsals, and is properly included in the same segment of the limb. The three principal metatarsals are interlocked together before they become anchylosed, the middle one being wedged into the back part of the interspace of the two lateral ones above, and into the fore part below, passing obliquely between them. The period at which these several constituents of the "tarso-metatarse" coalesce is shorter in the birds that can fly than in those that cannot; and the extent of the coalescence is least in the penguins, in which the true nature of the compound bone is best seen.

The modifications of the tarso-metatarse are chiefly manifested in its relative length and thickness, in the relative length of the three metatarsals, and in the number and complexity of the calcaneal processes.

The inner of the two cavities for the condyles at the proximal end of the bone is the "entocondyloid" cavity or surface, the outer one the "ectocondyloid" surface; they are separated by an "intercondyloid" tract, from the fore part of which there usually rises an intercondyloid tuberosity. The entocondyloid cavity is usually the largest and deepest: it is so in the raven, in which the base of the intercondyloid tubercle extends over the whole of the intercondyloid space. There are three calcaneal processes: one, called the "entocalcaneal," projects from below the entocondyloid cavity, and from the back part of the upper end of the entometatarse; a second, called the "mesocalcaneal," from the intercondyloid tract and the mesometatarse, and the third called "ectocalcaneal," from behind the ectocondyloid cavity and the ectometatarse. These three processes are united together by two transverse plates circumscribing four canals, two smaller canals being further carried between the ento- and meso-calcaneal processes. The primitive interosseous spaces are indicated by two small foramina at the upper and back part of the shaft, which converge as they pass forward, and terminate by a single foramen at the fourth part of the anterior concavity. A similar minute canal is retained between the outer and middle metatarsals, near their distal ends; each metatarsal then becomes distinct, and developes a convex condyle for the proximal phalanx. The middle one is the largest, and extends a little lower than the other two; it is also impressed by a median groove; the more compressed lateral condyles are simply convex, and are of equal length. A rough surface, a little way above the inner condyle, indicates the place of attachment of the small metatarsal of the hallux.

In the swan and other anserine birds the calcaneal prominence presents four longitudinal ridges, divided by three open grooves, the innermost ridge being the largest; the shaft is subquadrate, with the angles rounded, and none of the surfaces are channelled. The inner condyle scarcely extends before the base of the middle one; the canal perforating the outer intercondyloid space is bounded below by two small bars passing from the middle to the outer condyle, and which bars define the groove for the adductor muscle of the outer toe.

The tarso-metatarse of the diver (*colymbus*) is remarkably modified by its extreme lateral compression. The ento- and ecto-calcanea are prominent, oblong, subquadrate plates, inclining towards each other, but not quite circumscribing a wide intermediate space. The broad outer and inner surfaces of the shaft are nearly flat; the narrow fore and back surfaces are channelled; the anterior groove leads to the wide canal, perforating obliquely the shaft above the outer intercondyloid space, from which a narrower canal conducts to that interspace. The middle and outer trochleæ are nearly equally developed; the inner one stops short at the base of the middle one.

The number of toes varies in different birds; if the spur of the cock be regarded as a rudimental toe (which is not, however, my view of it), it may be held to have five toes, while in the ostrich the toes are reduced to two. Birds, moreover, are the only class of animals in which the toes, whatever be their number or relative size, always differ from one another in the number of their joints or phalanges, yet at the same time present a constancy in that variation.

The innermost or back toe, *i* (Fig. 24), answering, as I believe, to the "hallux," or innermost digit of the pentadactyle foot, has two phalanges; the second toe, *ii*, has three, the third toe, *iii*, four, and the fourth toe, *iv*, five phalanges; I believe the toe answering to the fifth in lizards and other pentadactyle animals to be wanting in the bird's foot, and the spur, sometimes single, sometimes double, as in *Pavo bicalcaratus*, to be a superadded weapon to the metatarse. As the toes in the tridactyle emeu, cassowary, and bustard, have respectively three phalanges, four phalanges, and five phalanges, we recognise them as answering to the second, third, and fourth in other birds; the toes in the didactyle ostrich have respectively four and five phalanges, and what is here truly suggestive, the outermost, which is much the smallest and shortest toe, has the greater number of joints, viz., five, thus retaining its ornithic type, as the fourth, or outermost, toe.

The entire form of the body, and consequently that of its bony framework, in a bird, has special reference to the power of flight. The trunk is an oval with the large end forwards. The vertebral column of this part is short and almost inflexible, so that the muscles act to great advantage; the spine of the neck being long and flexible, the centre of gravity is readily changed from above the feet—as when standing or walking—to between and beneath the wings during flight; when suspended in the air the bird's body naturally falls into that position, which throws the centre of gravity beneath the wings. The axis of motion being situated in a different place in the line of the body when walking from that which is used when flying, the discrepancy requires to be compensated by some means in all birds, in order to enable them to perform flight with ease. Raptorial birds take a horizontal position when suspended in the air, and the compensating power consists in their taking a more or less erect position when at rest. Another class, including the woodpeckers, wagtails, &c., take an oblique position in the air; with these the compensating power consists in their cleaving and passing through the air at an angle coincident with the position of the body, and performing flight by a series of curves or saltations. Natatorial birds sometimes need very extended flight; they take a very oblique position in the air, stretch out their legs behind and their neck in front; they have the ribs greatly lengthened, the integuments of the abdomen are long and flexible, which enables them greatly to enlarge the abdominal portion of their bodies by inflating it with air; this causes a decrease in the specific gravity of that part, and raises it to a horizontal position; the compensating power consists in the posterior half of the body becoming specifically lighter, while the specific gravity of the anterior half remains unaltered. When they alight they drop the legs, throw back the trunk by bending the knee-joint, and bring the head over the trunk by a graceful sigmoid curve of the long neck, as in Fig. 24. The act of swimming is rendered easy by the specific gravity of the body, by the boat-like shape of the trunk, and by the conversion of the hinder extremities into oars, in consequence of the membranes uniting the toes together. The effect of these web-feet in water is further assisted by the toes having their membranes lying close together when carried forwards; whilst, on the contrary, they are expanded in striking backwards. The oar-like action of the legs is still further favoured by their backward position,—an arrangement, however, which is unfavourable for walking.

Borelli was the first who, by comparison of the anatomical peculiarities of the human frame and the structure of birds, demonstrated, to a certain extent, the impossibility of the realization of the cherished project of flying by man. He arrived at this conclusion from a comparison of the form and strength of the muscles of the wings of birds with the corresponding muscles of the human body.

Principal Forms of the Skeleton in the Class Mammalia.—In the class Mammalia, which includes the hairy quadrupeds with the naked apodal whales and biped man, the form of the animal is modified for a great diversity of kinds and spheres of locomotion. Some live exclusively in the ocean, and cleave the liquid element under the form and with the locomotive powers of fishes; some frequent the fresh waters; some pass a subterraneous existence, and work their way through the solid earth; some mount aloft to seek and seize their prey in the air; some pass their lives in trees; most, however, dwell on the earth, with various powers of walking, running, and leaping. Lastly, man is modified to sustain his frame erect on the hinder, now become in him the lower, limbs.

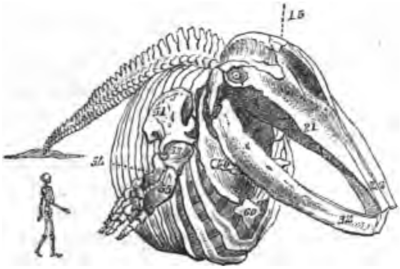
In the Mammalian class, accordingly, we find the limbs progressively endowed with more varied and complicated powers. They retain in the *Cetacea* (whale and porpoise tribe) their primitive form of flattened fins; in the *Ungulata* (hoofed beasts) one or more of the digits acquire the full complement of joints, but have the extremity enveloped in a dense hoof; in the *Unguiculata* (quadrupeds with claws) the limbs, with ampler proportions, have the digits liberated, and armed with claws confined to the upper surface, leaving the under surface of the toes free for the exercise of touch; in the mole the hand is shortened, thickened, expanded, and converted into a sort of spade; in the bat the fingers are lengthened, attenuated, and made outstretchers and supporters of a pair of wings; in the *Quadrumana* (ape and monkey tribes) certain digits are endowed with special offices, and by a particular position enabled to oppose the others, so as to seize, retain, and grasp. Lastly, in *Man* the offices of support and locomotion are assigned to a single pair of members; the anterior, and now the upper, limbs being left free to execute the various purposes of the will, and terminated by a hand, which, in the matchless harmony and adjustment of its organization, is made the suitable instrument of a rational being.

In contemplating and comparing the skeletons of a series of mammals, the most striking modifications are observable in the structure and proportions of the limbs.

There are a few osteological characters in which all mammalia agree, and by which they differ from the lower vertebrata; and some have been supposed to be peculiar to them that are not so. The pair of occipital condyles, *e. g.*, developed from the exoccipitals, are a repetition of what we saw in the batrachia. The flat surfaces of the bodies of the trunk-vertebræ were a character of many extinct reptiles; but these surfaces in mammals are developed on separate epiphysial plates, which coalesce in the course of growth with the rest of the centrum. Moveable ribs, projecting freely (pleurapophyses) in the cervical region, may be found in a few exceptional cases (sloths, monotremes); bony sternal ribs (hæmapophyses) exist in most *Edentata;* a coracoid extending, as in birds and lizards, from the scapula to the sternum, with an "epicoracoid," as in lizards, is present in the monotremes (platypus or duck-mole, and echidna or spiny ant-eater, of Australia); the cotyloid cavity may be perforated in the same low mammals as in birds; the digits may have the phalanges in varying number in the same hand, and exceeding three in the same finger, *e. g.*, in the whale tribe. But the following osteological characters are both common and peculiar to the mammalia. The squamosal, 27, or second bone of the bar continued backwards from the maxillary arch, is not only expended as in the chelonia, but develops the articular surface for the mandible, and this surface is either concave at some part or is flat; each half or ramus of the mandible is ossified from a single centre, and consists of one piece; and the condyle is either convex or is flat, never concave. The presphenoid (centrum of the parietal vertebra) is developed distinctly from the basisphenoid; it may become confluent, but is not connate, therewith.

One known mammal (the three-toed sloth) has more, and one (the manatee or sea-cow) has less than seven vertebræ of the neck. In the rest of the class these vertebræ, which have the pleurapophyses short and usually anchylosed, are seven in number.

Fig. 25.



FORE-SHORTENED VIEW OF THE SKELETON OF A WHALE (*Balænoptera boops*), SHOWING ITS RELATIVE SIZE TO MAN.

Skeleton in the Cetacea or Whale Tribe.—In the skeleton of the whale (Fig. 25), which to outward appearance seems to have as little neck as a fish, there are as many cervical vertebræ as in the long-necked giraffe: this is a very striking instance of adherence to type within the limits of a class: the adaptation to form and function is effected by a change of proportion in the bones; the cervical vertebræ in the whale are flattened from before backwards into broad thin plates; in the giraffe (Fig. 30) they are produced into long subcylindrical bones. In the whales the movements of these vertebræ upon one another are abrogated, and in the grampus and porpoise the seven vertebræ are blended together into a single bone; they thus give a firm and unyielding support to the large head, which has to overcome the resistance of the water when the rapid swimmer is cleaving its course through that element. The dorsal vertebræ are characterized in all mammalia by the sudden increase in the length and size of the ribs, which, in a certain number of these vertebræ, including the first, are joined to a breast-bone by a commonly cartilaginous, rarely osseous, part. The first rib is remarkable for its great breadth in the whale; this and a few following ribs are joined to a short and broad and often perforated sternum (Fig. 25), No. 60; the remaining ribs are free, or, as they would be called in Human Anatomy, "false." They are articulated to the ends of diapophyses, which progressively increase in length to the end of the dorsal series. Then follow vertebræ without ribs, answering to those called "lumbar." The whole hinder part of the trunk of whales being needed to effect the strokes by which they are propelled, its vertebræ are as free from anchylosis as in fishes; there is consequently no "sacrum," and the caudal vertebræ are counted from the first of those that have "chevron bones" articulated to their under part. This special name is given to the vertebral elements called "hæmapomophyses" (see Fig. 26, *h*), which are articulated in cetacea as in crocodilia, directly to the under surface of the centrum, and, coalescing at their opposite ends, develope thence a "hæmal spine," and form a "hæmal" canal analogous to, but not homologous with, that in fishes (compare No. V, *h*, with No. I, *p*, in Cut 10, p. 182). The caudal vertebræ of whales further differ from those in fishes in retaining the transverse processes, and in becoming flattened from above downwards, without coalescing. These modifications relate to the support of a caudal fin, which is extended horizontally instead of vertically.

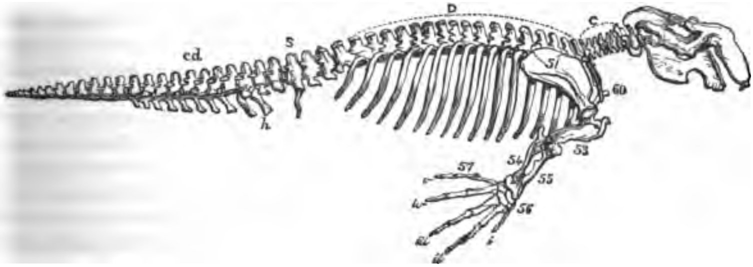
Whales and porpoises progress by bounding movements or undulations in a vertical plane, and their necessity of coming to the surface to inhale the air directly, as warm-blooded mammals, calls for a modification in the form of the main swimming instrument, such as may best adapt it to effect an easy and rapid ascent of the head.

The course of the whale is stopped and modified by the action of the pectoral limbs, which are the same parts as those in fishes, but constructed more after the higher vertebrate type. The digital rays do not exceed five in number; but they consist of many flattened phalanges, and are enveloped in a common sheath of integument. A radius, 55, and an ulna, 54 (Fig. 25), support the carpal series; but, instead of being directly articulated to the scapular arch, they are suspended to a humerus, 53: this is a short, thick bone, with a rounded head. The scapula, 51, is detached from the occiput, has a short, stunted, coracoid anchylosed to it, and is thus freely suspended in the flesh; it developes an acromial process: the ulna, 54, is produced upwards into an olecranon. With all those marks, however, of adhesion to the mammalian type of fore-arm, the outward aspect of the limb is as simple as is that of the fish's fin; it moves, as by one joint, upon the trunk, and is restricted to the functions of a pectoral fin.

In the huge skull of the whale the broad vertical occiput may be noticed, by which the head is connected, through the medium of a short consolidated neck, with the trunk; the whole cranium seems to have been compressed above, from before backwards, so that the small nasal bones, 15, articulating with the short and very broad frontals, form the highest part of the skull. The long maxillaries, 21, and premaxillaries, 22, extend backwards and upwards, to articulate with the nasals, and complete with them the bony entry to the air-passages, situated so favourably at the summit of the cranium. The nostrils, formed by the soft parts guarding that entry, are called "blow-holes;" they are double in the whales—single in the smaller cetacea. In the whales the "baleen" or "whalebone" plates are attached to the palatal surface of the maxillary and premaxillary bones; the expanded toothless mandible supports an enormous under lip, which covers the whalebone plates when the mouth is shut. The skeleton of the great finner whale (*Balænoptera boops*), from which the foreshortened view (Cut 25) is taken, was ninety-six feet in length; the relative dimensions of man is given by the outlines of the skeleton at its side. No known extinct animal of any class equalled this living Leviathan in bulk.

There are a few whale-like mammals, equally devoid of rudiments of hinder limbs, which obtain their sustenance from sea-weeds or sea-side herbage. They have teeth adapted for bruising such substances, and the movements of the head in grazing require the cervical vertebræ to be unanchylosed; these are, however, short, and in the manatee but six in number. In the dugong (Fig. 26), one of these herbivorous sea-mammals frequenting the Malayan and Australian shores, the upper and lower

Fig. 26.



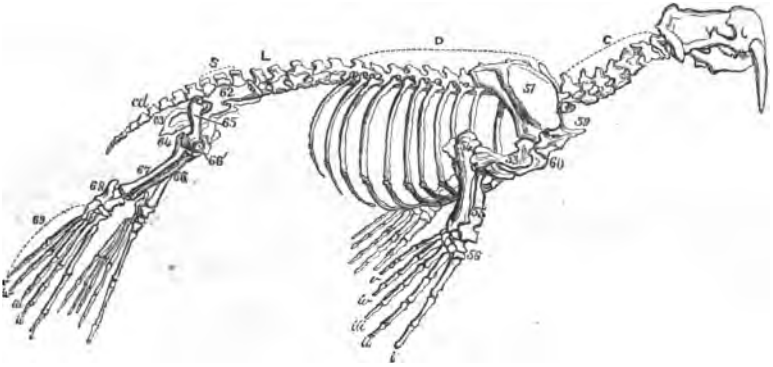
SKELETON OF THE DUGONG (*Halicore Australis*).

jaws are singularly bent down, and the upper jaw is armed with a pair of short tusks. The bones of all these cetacea are singularly massive and compact. Three or four of the anterior thoracic ribs are joined to a sternum—the rest are free. One of the vertebræ intervening between the costal and caudal series has connected with it a simple pelvic arch, in which the ilium and ischium may be recognised, and a still more rudimental condition of such arch is suspended in the inguinal muscles of the true cetacea. Most of the caudal vertebræ (Fig. 26), *cd*, of the manatee and dugong, have long diapophyses, and hæmal arches (Fig. 26), *h*. The terminal vertebræ are flattened horizontally.

The lacteal organs of the dugong are placed on the breast, and the pectoral fins, in the female at least, are applied to clasp the young; and the animal so observed, with its own head and that of its young above water, has given rise to the fable of the siren and mermaid. The bones and joints of the pectoral fin are accordingly better developed than in the ordinary whales. The first row of carpal bones, 56, consists of two—one articulated to the radius, 55, the other to the ulna, 54, and fifth digit, 57, *v*, and both to the single bone representing the second row. The first digit, *i*, consists of a short metacarpal; the metacarpals of the others support each three phalanges.

Skeleton of the Seal.—In the seal tribe (*Phocidæ*) another and well-marked stage is gained in the development of the terrestrial instruments of locomotion. Hind limbs are now added — the marine mammal has become a quadruped. The sphere of life of the seals is near the shores; they often come on land; they sleep and bring forth among the rocks and littoral caves: hence the necessity for a better development of the pectoral limbs, although these, like the pelvic ones, still retain the general form of fins. The fish-hunting seals make more use of the head in independent movements of sudden extension, retraction and quick turns to the right and left, than do the cetacea of like diet; and the walrus (Fig. 27) works the head, as the place of attachment of its long, vertical, down-growing tusks, in various movements required in clambering over floes and bergs of ice. Accordingly, in the seal tribe we find the seven neck vertebræ (*ib.*) *c*, longer, and with more finished and free-playing joints than in the whales and dugongs. The sigmoid curve, in which they can be thrown during retraction of the head, exceeds

Fig. 27.



SKELETON OF THE WALRUS (*Trichecus rosmarus*).

that in most other mammals, and almost reminds one of the extent of flexion of this part of the spine in birds.

In the walrus, the skeleton of which is here selected to exemplify the phocal modification of the mammalian skeleton, the vertebral formula is:—7 cervical, C, 11 dorsal, D, 5 lumbar, L, 3 sacral, S, and 9 caudal, *cd*. As, in consequence of the presence of hind-limbs, a sacrum is now established, the characters of the above five kinds of body-vertebræ, as defined in man and other mammals, may here be given: the cervical or neck vertebræ "have perforated transverse processes," the dorsal vertebræ "bear ribs;" the lumbar vertebræ "have imperforate transverse processes and no ribs;" the sacral vertebræ "are anchylosed together;" the rest are caudal vertebræ whatever their modifications. In the above characters, the term "rib" is given to the vertebral element called "pleurapophysis," when this is long and moveable; that element may be, and often is, present, but short and fixed, in both cervical, lumbar, sacral, and caudal vertebræ; in some mammals, *e.g.*, monotremes, the pleurapophysis may remain unanchylosed in some of the neck-vertebræ, but it is short, like a transverse process; and the so-called "perforated transverse process" in all mammals consists of the diapophysis, parapophysis, and pleurapophysis; the hole being the interval between those parts: in the lumbar vertebræ the pleurapophysis is short, and confluent or connate with the diapophysis.

Returning to the skeleton of the walrus, we find that nine pairs of ribs directly join the sternum, which consists of eight bones. The transverse processes of the last cervical are imperforate, consisting of the diapophysis only. The neural arches of the middle dorsal vertebræ are without spines and very narrow, leaving wide unprotected intervals of the neural canal. The bones of the neck are modified to allow of great extent and freedom of inflection. The perforated transverse processes of the third to the sixth cervicals inclusive are remarkable for the distinctness of their constituent parts. Inferior ridges and tuberous processes, called "hypapophyses," are developed from some dorsal and lumbar vertebræ. These processes indicate the great development of the anterior vertebral muscles, *e.g.* the "longi colli" and "psoæ," and relate to the important share which the vertebræ and muscles of the trunk take in the locomotion of the seal-tribe, especially when on dry land, where they may be called "gastropods," in respect of their peculiar mode of progression. The walrus alone seems to have the power of supporting itself on the fore fins, so as to raise the belly from the ground. There is no trace of clavicle in any seal. The upper part of the scapula exceeds the lower one in breadth. The spine terminates by a short and simple acromion. The humerus is short and thick, and is remarkable for the great development of the inner tuberosity and of the deltoid ridge, which is deeply excavated on its outer side. The inner condyle is perforated. The scaphoid and lunar bones are connate. Although the pollex or the first digit exceeds the third, fourth, and fifth in length, it presents its characteristic inferior number of phalanges, by which the front border of the fin is rendered more resisting. The pelvic arch is remarkable for the stunted development of the ilia, and the great length of the ischia and pubes. The femur is equally peculiar for its shortness and breadth. The tibia and fibula present the more usual proportions, and are anchylosed at their proximal ends. The bones of the foot are long, strong, and are modified to form the basis of a large and powerful fin: the middle toe is the shortest, and the rest increase in length to the margins of the foot; the inner toe has, nevertheless, but two phalanges, the rest having three phalanges, whatever their length; and this is the typical character, both as to the number of the digits and their joints, in both fore and hind feet of the mammalia.

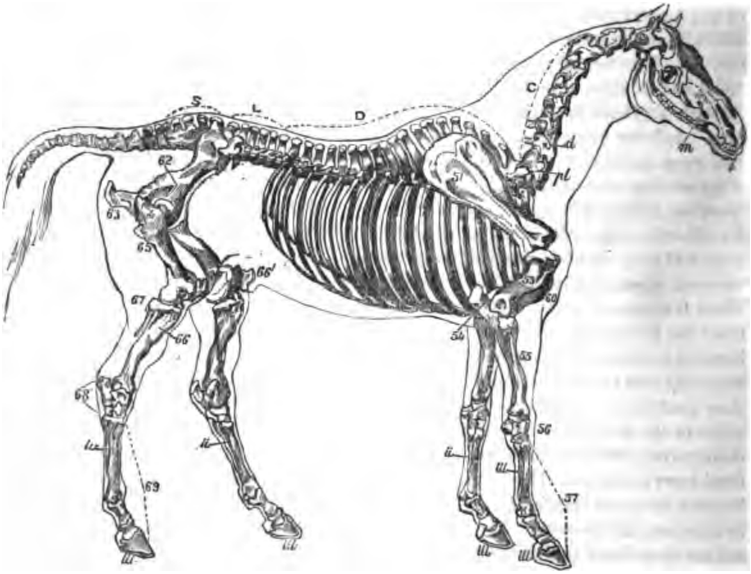
In the living walrus and seal the digits of each extremity are not only bound together by a common broad web of skin, but those of the hind-limbs are closely connected with the short tail: being stretched out backwards, they seem to form with it one great horizontal caudal fin, and they constitute the chief locomotive organ when the animal is swimming rapidly in the open sea. The long bones of seals, like those of whales, are solid.

With regard to the skull in the seal-tribe, it may be remarked that an occipito-sphenoidal bone is formed, as in man, by the coalescence of the basioccipital with the basisphenoid; the parts of the dura mater or outer membrane of the brain, called "tentorium," with the posterior part of the "falx," are ossified. The sella turcica is shallow, but well defined behind by the overhanging posterior clinoid processes: the petrosal shows a deep transverse cerebellar fossa, and is perforated by the carotid canal The frontal forms a small rhinencephalic fossa, and contributes a very large proportion to the formation of the orbital and olfactory chambers.

In Fig. 27, 62 is the ilium, 63 the ischium, and 64 the pubes, 65 is the femur, or thigh-bone, 66 the tibia, 66′ the patella or knee-pan, 67 the fibula, 68 the tarsus, and 69 the metatarsus and phalanges of the hind-foot; the numbers on the other bones correspond with these in the skeleton of the dugong.

Skeletons of Hoofed Quadrupeds—The Horse.—The contrast, as regards the sphere of life and kind of movement between the seal and the horse is very great; the instruments of locomotion, and indeed the whole frame, need to be very different in an animal that can only shuffle on its belly along the ground, and one that can

Fig. 28.



HORSE (*Equus caballus*).

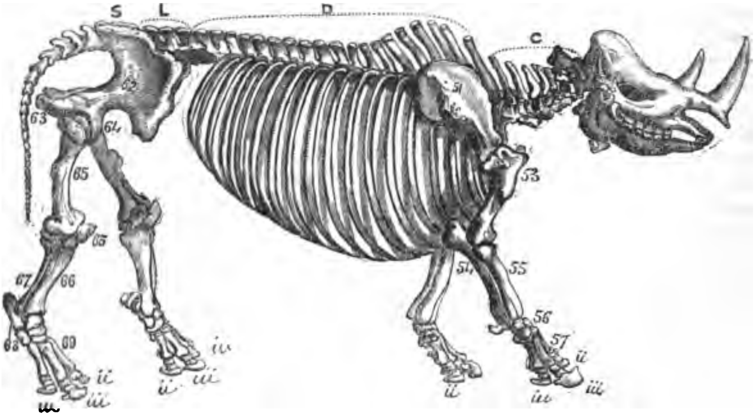
traverse the surface of the earth at the rate of four miles in six minutes and a half, as was achieved by the noted racer "Flying Childers." The modifications in the form and proportions of the locomotive members are accordingly extreme. The limbs in the horse are as remarkable for their length and slenderness, as in the seal for their brevity and breadth. Both fore and hind limbs in the horse terminate each in a single hoof; the trunk is raised high above the ground, and is more remarkable for its depth than breadth, especially at the fore part; the neck is long and arched; the jaws long and slender, being produced so as to facilitate the act of cropping the grass, and leaving so much space between the front teeth, *i*, and the grinders, *m*, as permits man to insert the instrument called "bit" into the mouth, whereby he masters and guides his noble and valuable four-footed ally, as the ship is steered by the helm.

Were every animal constructed expressly and exclusively for its own peculiar habits of life, and irrespective of any common pattern, it could scarcely be expected, beforehand, that the same bones would be found in the horse as in the seal; yet a comparison of their skeletons, Cuts 27 and 28, will demonstrate that this is, to a very great degree, the case.

The vertebral formula of the horse is:—7 cervical, C, 19 dorsal, D, 5 lumbar, L, 5 sacral, S, and 17 caudal. Eight pairs of ribs directly join the sternum, 60, which consists of seven bones and an ensiform cartilage. The neural arches of the last five cervical vertebræ expand above into flattened, subquadrate, horizontal plates of bone, with a rough tubercle in place of a spine: the zygapophyses, *z*, are unusually large. The perforated transverse process sends a pleurapophysis, *pl*, downwards and forwards, and a diapophysis, *d*, backwards and outwards, in the third to the sixth cervicals inclusive: in the seventh the diapophysial part alone is developed, and is imperforate. The spinous processes suddenly and considerably increase in length in the first three dorsals, and attain their greatest length in the fifth and sixth, after which they gradually shorten to the thirteenth, and continue of the same length to the last lumbar. The lumbar diapophyses are long, broad, and in close juxtaposition; the last presents an articular concavity adapted to a corresponding convexity on the fore part of the diapophysis of the first sacral. The scapula, 51, is long and narrow, and according to its length and obliquity of position the muscles attached to it, which act upon the humerus, operate with more vigour, and to this bone the attention of the buyer should be directed, as indicative of one of the good points in a horse. The coracoid is reduced to a mere confluent knob. The spine of the scapula, 51, has no acromion. The humerus, 53, is remarkable for the size and strength of the proximal tuberosities in which the scapular muscles are implanted. The joint between it and the scapula is not fettered by any bony bar connecting the blade-bone with the breast-bone; in other words, there is no clavicle. The ulna, represented by its olecranal extremity, 54, is confluent with the radius, 55. The os magnum in the second series of carpal bones, 56, is remarkable for its great breadth, corresponding to the enormous development of the metacarpal bone of the middle toe, which forms the chief part of the foot. Splint-shaped rudiments of the metacarpals, answering to the second, *ii*, and fourth, *iv*, of the pentadactyle foot, are articulated respectively to the trapezoides and the reduced homologue of the unciforme. The mid-digit, *iii*, consists of the metacarpal, called "cannon-bone," and of the three phalanges, which have likewise received special names in Veterinary Anatomy, for the same reason as other bones have received them in Human Anatomy. "Phalanges" is the "general" term of these bones, as being indicative of the class to which they belong, and "hæmapophyses" is the "general" term of parts of the inferior arches of the head-segments; and just as, from the modifications of these hæmapophyses, they have come to be called "maxilla," "mandibula," "ceratohyal," &c., so the phalanges of the horse's foot are called—the first, "great pastern bone," the second, "small pastern bone," and the third, which supports the hoof, the "coffin bone;" a sesamoid ossicle between this and the second is called the "coronary." The ilium, 52, is long, oblique, and narrow, like its homotype, the scapula; the ischium, 63, is unusually produced backwards. The extreme points of these two bones show the extent to which the bending muscles and extending muscles of the leg are attached; and according to the distance of these points from the thigh-bone the angle at which they are therein inserted becomes more favourable for their force; the longer, therefore, and the more horizontal the pelvis, the better the hind-quarter of the horse, and its qualities for swiftness and maintenance of speed depend much on the "good point" due to the development of this part of the skeleton. The femur, 65, is characterized by a third trochanter springing from the outer part of the shaft before the great trochanter. There is a splint-shaped rudiment of the proximal end of the fibula, 67, but not any rudiment of the distal end. The tibia, 66, is the chief bone of the leg. The heel-bone, "calcaneum," is much produced, and forms what is called the "hock." The astragalus is characterized by the depth and obliquity of the superior trochlea, and by the extensive and undivided anterior surface, which is almost entirely appropriated by the naviculare. The external cuneiforme is the largest of the second series of tarsals, being in proportion to the metatarsal of the large middle digit, *iii*, which it mainly supports. The diminished cuboides articulates partly with this, partly with the rudiment of the metatarsal corresponding with that of the fourth toe, *iv*. A similar rudiment of the metatarsal of the toe, corresponding with that of the second, *ii*, articulates with a cuneiforme medium—here, however, the innermost of the second series of tarsal bones.

Of all the other known existing hoofed quadrupeds, it would hardly be anticipated that the rhinoceros presented the nearest affinity to the horse; one might rather look to the light camel or dromedary; but a different modification of the entire skeleton may

Fig. 29.



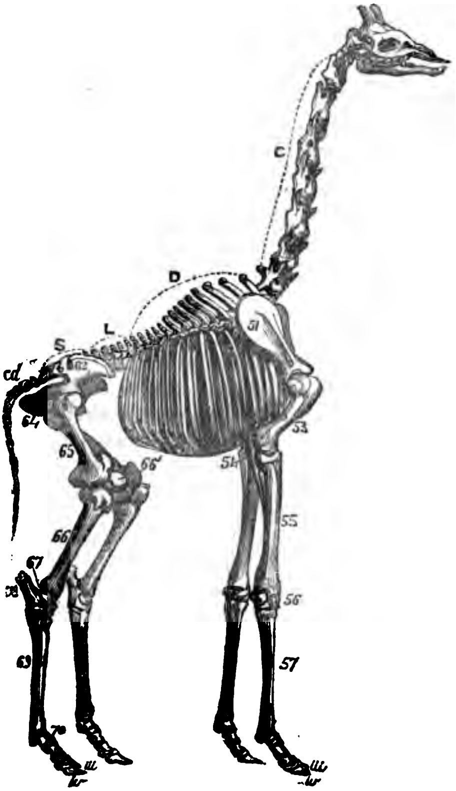
SKELETON OF THE RHINOCEROS (*Rh. bicornis*).

be traced in the animals with toes in even number, as compared with the horse and other odd-toed hoofed quadrupeds. In an extinct kind of horse (*Hippopotherium*), the two splint-bones are more developed, and each supports three phalanges, the last being provided with a diminutive hoof. In the extinct *Palæotheria* the outer and inner digits acquired stronger proportions, and the entire foot was shortened. The transition from the *Palæotheria*, by the extinct hornless rhinoceros (*Acerotherium*), to the existing forms of rhinoceros, is completed. In the skeleton of the rhinoceros we find resemblances to the horse in the number of the dorsal vertebræ, in the third trochanter of the femur, and in the number of digits on each foot, albeit the two that are hidden and rudimental in the swifter quadruped are here made manifest in their full development: the concomitant shortening of the whole foot, and strengthening of the entire limbs, accord with the greater weight of the body to be supported, clad as it is with a coat-armour of thickened tuberculated hide: the broader feet, terminated each by three hoofs, afford a better basis of support in the swampy localities affected by the rhinoceros. Both scapulæ and iliac bones are of greater breadth, and less length. The ulna is fully developed in the fore-limb, and the fibula in the hind-leg; but there is no power of rotation of the fore-limb in any hoofed quadruped. The upper surface of the skull is roughened for the attachment of the horn, and in two distinct places where the species has two horns.

If the equine skull be compared with that of the rhinoceros, the basioccipital will be seen to be narrower and more convex. The true mastoid intervenes, as a tuberous process, between the post-tympanic and paroccipital processes, clearly indicating the true nature of the post-tympanic in the rhinoceros; the tapir shows an intermediate condition of the mastoid between the rhinoceros and horse. The latter differs from both the tapir and rhinoceros in the outward production of the sharp roof of the orbit and the completion of the bony frame of that cavity behind by the junction of the postorbital process with the zygoma. The temporal fossa, so defined, is small in proportion to the length of the skull: the base of the postorbital process is perforated by a superorbital foramen; the lacrymal canal begins by a single foramen. The premaxillaries extend to the nasals, and shut out the maxillaries from the anterior aperture of the nostrils. The chief marks of affinity to other odd-toed hoofed beasts (*Perissodactyles*) are seen in the shape, size, and formation of the posterior aperture of the nostrils, the major part of which is bounded by the palatine bones, of which only a small portion enters into the formation of the bony palate, which terminates behind opposite the interspace between the penultimate and last molars. A narrow groove divides the palato-pterygoid process from the socket of the last molar, as in the tapir and rhinoceros. The pterygoid process has but little antero-posterior extent: its base is perforated by the ectocarotid canal. The entopterygoids are thin plates applied like splints over the inner side of the squamous suture between the pterygoid processes of the palatines and alisphenoids. The postglenoid process in the horse is less developed than in the tapir. The eustachian process is long and styliform. There is an anterior condyloid foramen, and a wide "fissura lacera." The broad and convex bases of the nasals articulate with the frontals a little behind the anterior boundary of the orbits. The space between the incisors and molars is of greater extent than in the tapir; a long diastema is not, however, peculiar to the horse; and, although it allows the application of the bit, that application depends rather upon the general nature of the horse, and its consequent susceptibility to be broken in, than upon a particular structure which it possesses in common with the ruminants and some other herbivora.

The tapir and the rock cony have four digits on each fore-foot, and three digits on each hind-foot; but they resemble more the horse and rhinoceros than any other *Ungulata*. If the osteological characters of the hoofed animals with the hind digits in uneven number be compared together, they will be found to present, notwithstanding the differences of form, proportion, and size presented by the rhinoceros, hyrax, tapir, and horse, the following points of agreement, which are the more significative of natural affinity when contrasted with the skeletons of the hoofed animals with digits in even number. Thus, in the odd-toed or "perissodactyle" ungulates, the dorso-lumbar vertebræ differ in different species, but are never fewer than twenty-two; the femur has a third trochanter, and the medullary artery does not penetrate the fore part of its shaft. The fore part of the astragalus is divided into two very unequal facets. The os magnum and the digitus medius which it supports is large, in some disproportionately, and the digit is symmetrical; the same applies to the ectocuneiform and the digit it supports in the hind-foot. If the species be horned, the horn is single; or if there be two, they are placed on the median line of the head, one behind the other, each being thus a single or odd horn. There is a well-developed post-tympanic process, which is separated by the true mastoid from the paroccipital in the horse, but unites with the lower part of the paroccipital in the tapir, and seems to take the place of the mastoid in the rhinoceros and hyrax. The hinder half, or a larger proportion, of the palatines enters into the formation of the posterior nares, the oblique aperture of which commences in advance of the last molar, and, in most, of the penultimate one. The pterygoid process has a broad and thick base, and is perforated lengthwise by the ectocarotid. The crowns of the antepenultimate, as well as the penultimate and last premolars, are as complex as those of the molars; that of the last lower milk-molar is bilobed. To these osteological and dental characters may be added some important modifications of internal structure.

Fig. 30.



SKELETON OF THE GIRAFFE (*Camelopardalis giraffa*).

as, *e.g.*, the simple form of the stomach, and the capacious and sacculated cæcum, equally indicating the mutual affinities of the odd-toed or perissodactyle hoofed quadrupeds, and their claims to be regarded as a natural group of the Ungulata. Many extinct genera, *e.g.*, lophiodon, tapirotherium, palæotherium, hippotherium, acerotherium, macrauchenia, elasmotherium, coryphodon, have been discovered, which once linked together the now broken series of Perissodactyla, represented by the existing genera rhinoceros, hyrax, tapyrus, and equus.

Another series of hoofed quadrupeds is characterized by having their hoofs and digits in even number in both fore and hind feet. The majority of these have a pair, so developed as to serve as feet, and terminated by a pair of hoofs so shaped as to look like one split hoof, whence the name "cloven-footed" given to this predominant family of "artiodactyle," or even-toed beasts; the synonym "ruminant," indicative of the same great family, is deduced from the characteristic complexity of their act of digestion.

No food is more remote or distinct from flesh than grass. Extremities enveloped in hoofs are incapacitated from seizing and retaining a living prey, hence all hoofed mammals are necessarily herbivorous: hence the complexity of their grinding teeth, the concomitant strength of their grinding muscles, and weakness of the biting muscles; the length of the neck, to enable the head to reach the verdant earth, and the length and slenderness of the jaws. The absence of a clavicle, and of any power of rotating the bones of fore-leg and fore-foot, are also constant characteristics of both great divisions of the *Ungulata* or hoofed quadrupeds.

The ox, the hog, and the hippopotamus are examples of even-toed hoofed quadrupeds. In the ox, besides the two large and normally developed hoofs, two small supplementary hoofs dangle behind, in each foot; in the hog these are brought down to the level of the mid-pair, but are smaller; in the hippopotamus the four digits and hoofs are subequal on each foot. From this type of extremity to that of the giraffe, or camel, where the digits are absolutely restricted to two on each foot, there is a close series of gradational short-comings affecting the outer and the inner toes, until they wholly disappear. The giraffe (Fig. 31), is a ruminant dwelling in climes where herbage disappears from the parched soil soon after the rainy season has terminated, and where sustenance for a herbivore of its bulk could hardly be afforded, except by trees: it is therefore modified to browse on the tender branches, and chiefly of the light and lofty acacias. Its trunk is accordingly short, and raised high upon long and slender limbs, especially at the fore part; a small and delicate head is supported on an unusually long neck. The number of vertebræ here, however, accords with that characteristic of the mammalian class, viz., seven. They are peculiar for the length of their bodies. There are fourteen dorsal vertebræ with very long spinous processes, and supporting long and slender ribs, especially the anterior ones, seven pairs of which join the sternum, which consists of six bones; the lumbar vertebræ are five in number, the sacral four, and the caudal twenty; this series is terminated in the living animal by a tuft of long, wavy, stiff black hair, forming an admirable whisk to drive off insect tormentors. The blade-bone, 51, is remarkably long and slender; its spine or ridge forms a very low angle, and gradually subsides as it approaches the neck of the scapula; the coalesced coracoid is a large tuberosity. The humerus, 53, forms the shortest of the three segments of the limb; it is remarkable for the strength of the proximal processes; the second segment is chiefly constituted, as in all ruminants, by the radius, 55; the slender shaft of the ulna, 56, which supports a long olecranon, becomes blended with the radius, and lost at its lower third, but its distal end reappears as a distinct part. The metacarpals of the retained digits, answering to the third and fourth in the human and other five-fingered (pentadactyle) hands, are blended together to form a single "cannon-bone" of the veterinarians; but the nature of this is different from that in the horse; it divides at its distal end into two well-formed trochleæ, or pulley-joints, and to these are articulated the digits *iii* and *iv*, which each consist of three joints or phalanges. Thus the main extent of this singularly elongated limb is gained by the excessive development of the hand-segment, restricted, however, to those elements that answer to the middle and ring-fingers of the human hand.

The pelvis, of which the sacral, S, iliac, 62, and ischial, 64, elements are shown in Cut 31, is small in proportion to the animal's bulk. The femur, 65, is short like the humerus, and chiefly remarkable for the great expanse of its distal end. The tibia, 66, forms the main basis of the leg, as its homotype the radius does in the fore-arm, but the fibula is more reduced than in the ulna; rarely in any ruminant is more of it visible than its distal end, 67, wedged in between the tibia and the calcaneum. The series of tarsal bones, 68, is peculiar in all ruminants for a coalescence of the two bones answering to the "scaphoid and cuboid" in the human tarsus. In all ruminants the astragalus is unusually symmetrical in shape, with a deep trochlear articular surface for the tibia, and two equal convex surfaces for succeeding tarsal bones; the calcaneum is produced into a long "hock." The rest of the bones of the hind-foot conform closely with those of the fore-foot.

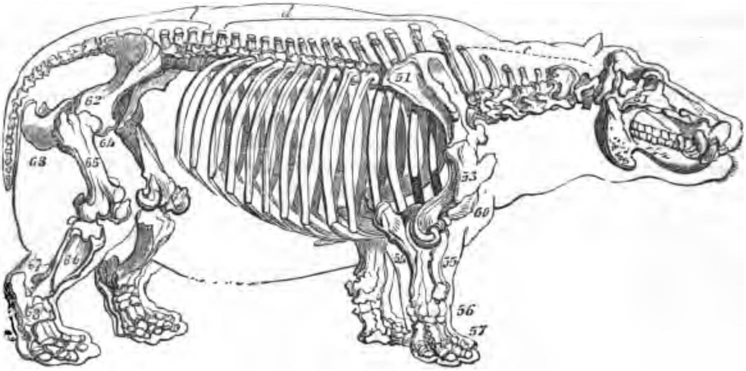
A few remarks, although interesting chiefly to the professed anatomist, appear called for in reference to the bony structure of the head of the giraffe.

The exoccipitals form a marked protuberance above the foramen magnum, and below a deep fossa, for the implantation of the ligamentum nuchæ—the length of the dorsal spines being related, in all ruminants, to a due surface for the attachment of this strong elastic support of the head and neck. The parietals are chiefly situated on the upper surface of the skull; the osseous horn-cores, which are originally distinct, become anchylosed in old giraffes, across the coronal suture, equally to the parietals and frontals: if one of these be divided longitudinally, it will show the extension of the frontal and parietal sinuses into its lower fourth, the rest of the horn-core being a solid and dense bone. The protuberance upon the frontal and contiguous parts of the nasal bones is entirely due to an enlargement of those bones, and not to any distinct osseous part: its surface is roughened by vascular impressions. The lacrymal is separated from the nasal by a large vacuity intervening between those bones, the frontal and the maxillary. The premaxillaries, which are of unusual length, articulate with the nasals. The petrotympanic is a separate bone, as in all ruminants. The symphysis of the lower jaw is unusually long and slender in the giraffe.

In the skeleton of the Camel (*Camelus bactrianus*) the vertebral formula is—seven cervical, twelve dorsal, seven lumbar, four sacral, eighteen caudal. Seven pairs of ribs articulate directly with the sternum, which consists of six bones, the last being greatly expanded and protuberant below, where it supports the pectoral callosity in the living animal. The cervical region, though less remarkable for its length than in the giraffe, is longer than in ordinary ruminants, and is remarkable for its flexuosity; the vertebræ are peculiar for the absence of the perforation for the vertebral artery in the transverse process, with the exception of the atlas; that artery, in the succeeding cervicals, enters the back part of the neural canal, and perforates obliquely the fore part of the base of the neurapophysis. The costal part of the transverse process is large and lamelliform in the fourth to the sixth cervical vertebræ inclusive: in the seventh it is a short protuberance. The spinous process of the first dorsal suddenly exceeds in length that of the last cervical, and increases in length to the third dorsal; from this to the twelfth dorsal the summits of the spines are on almost the same horizontal line, and are expanded and obtuse above, sustaining the substance of the two humps of this species; they afford, however, no other indication of those risings, which are as independent of the osseous system as is the dorsal fin in the grampus or porpoise. The spines of the lumbar vertebræ progressively decrease in length. The spine of the scapula is produced into a short-pointed acromion: the coracoid tubercle is large, and grooved below. The ridge upon the outer condyle of the humerus is much less marked than in the normal ruminants. The ulna has coalesced more completely with the radius, and appears to be represented only by its proximal and distal extremities. The carpal bones have the same number and arrangement as in ordinary ruminants, but the pisiforme is proportionally larger. There is no trace of the digits answering to the first, second, and fifth in the pentadactyle foot: the metacarpals of those answering to the third and fourth have coalesced to near their distal extremities, which diverge more than in the ordinary ruminants, giving a greater spread to the foot, which is supported by the ordinary three phalanges of each of those digits. The last phalanx deviates most from the form of that in the ordinary ruminants by its smaller proportional size, rougher surface, and less regular form: it supports, in fact, a modified claw rather than a hoof. In the femur the chief deviation from the ordinary ruminant type is seen in the position of the orifice of the canal for the medullary artery, which, as in the human skeleton, enters the back part of the middle of the shaft, and inclines obliquely upwards. The fibula is represented by the irregularly-shaped ossicle interlocked between the outer side of the distal end of the tibia and the calcaneum. The scaphoid is not confluent with the cuboid as in the normal ruminant: the rest of the hind-foot deviates in the same manner and degree from the ordinary ruminant type, as does the fore-foot.

The camel tribe have no horns: some small deer of the musk-family are compensated for the want of horns by very long and sharp upper canine teeth; the rest of the ruminants, either in the male sex or in both sexes, are endowed with the weapons of offence and defence, developed from and supported by the head, called "horns" and "antlers." The term "horn" is technically restricted to the weapon which is composed of a bony base, covered by a sheath of true horny matter. Such horns are never shed; and as, in order to diminish the weight of the head, the horn-core is made as hollow as is consistent with strength, the ruminants with such horns are called hollow-horned: the ox, the sheep, and the antelope are examples. Antlers consist of bone only. During the period of their growth they are covered by a vascular, short-haired skin like velvet; but when their growth is completed, this skin dries and peels off, leaving the antler a solid, naked, and insensible weapon. Being deprived, however, of its vascular support it dies, and, after a certain period of service, is undermined by the absorbents and cast off. The process of growth and decadence of the antlers is repeated each year; and in the fallow-deer the antlers progressively acquire greater size and more branches to the sixth year, when the animal is in its prime. Good evidence has been obtained that the same law of growth, shedding, and annual renewal prevailed in the gigantic fossil deer of Ireland, in which upwards of eighty pounds of osseous matter must have been developed from the frontal bones every year in the full-grown animal. The ruminants of the deer and elk tribes are those which have antlers, or are "solid-horned." The horns of the giraffe are peculiar; they are short and simple, are always covered by a hairy integument, and are never shed. They relate in position to both the frontal and parietal bones. In all other ruminants, the horns are developed from the frontals exclusively, although they sometimes, as in the ox, project from the back part of the cranium; but the frontals, in such cases, extend to that part. The horn of the rhinoceros consists wholly of fibrous horny matter.

Fig. 31.



SKELETON OF THE HIPPOPOTAMUS AMPHIBIUS.

The even-toed hoofed animals that do not ruminate have no horns. The osteology of this division is here illustrated in the hippopotamus (Fig. 31). The skeleton, in its strength and massiveness, presents a greater contrast with that of the giraffe than the rhinoceros's skeleton does with that of the horse; there are, nevertheless, as will be shown in the concluding summary, more essential points of resemblance to the giraffe's skeleton than to that of the rhinoceros. In points of minor importance, we find the hippopotamus resembling the rhinoceros; as *e.g.* in the shortness and strength of its neck; but it has only fifteen dorsal, *d*, and four lumbar, *l*, vertebræ. The spines of these vertebræ are shorter and less unequal than in the ruminants; and they have an almost uniform direction, as in all quadrupeds that do not move by leaps or bounds. The tail is short, and, in the living animal, compressed, acting like a rudder. The bones of the limbs are short and thick. In the scapula, 51, the acromion is slightly produced, and the coracoid recurved. The great tuberosity of the humerus, 53, is divided into two subequal processes. The ulna and radius have coalesced at their extremities, and at the middle of their shaft, the interosseous space being indicated by a deep groove and two holes. In the carpal series of bones, the trapezium is present, but does not support any digit; the innermost, answering to the thumb or pollex, therefore, is the one which is absent; of the remaining four digits, the two middle ones, answering to the third and fourth, are most developed. The femur has no third trochanter. The fibula is distinct from the radius, and extends from its proximal end to the calcaneum. The entocuneiform bone is present in the tarsus, but there is no rudiment of the innermost toe or hallux; the proportions of the other four toes resemble those on the fore-foot.

The skull is remarkable for the prominence and high position of the orbits, which allow the eye to be projected above the surface of the water, and a survey to be made by the suspicious animal without the exposure of any other part of the head. The upper jaw is peculiar for the development of the sockets of the great canine teeth, and the lower jaw combines with the like character an unusual production and curvature of the angle.

With regard to the osteology of the hog tribe, our limits compel us to restrict ourselves to the notice of the still more singular development of the sockets of the upper canines or tusks in the babyroussa, in which those teeth curve upwards and pierce the skin of the face, like horns, whence the name "horned hog" sometimes imposed upon it.

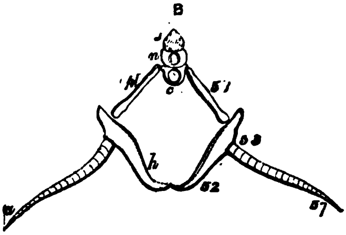
If the hoofed animals with the digits in even number be compared together, in regard to their osteological characters, they will be found, notwithstanding the difference of form, proportion, and size presented by the hippopotamus, wild boar, vicugna, and chevrotain, to agree in the following points, which are the more significative of natural affinity when contrasted with the skeletons of the hoofed animals with digits in uneven number. Thus, in the even-toed or "artiodactyle" ungulates, the dorso-lumbar vertebræ are the same in number, as a general rule, in all the species, being nineteen. The rare exceptions appear to be due to the development, rarely to the suppression, of an accessory vertebra as an individual variety, the number in such cases not exceeding twenty or falling below eighteen, and the supernumerary vertebra being most usually manifested in the domesticated and highly-fed breeds of the common hog. The recognition of this important character appears to have been impeded by the variable number of moveable ribs in different species of the artiodactyles, the dorsal vertebræ, which these ribs characterize, being fifteen in the hippopotamus and twelve in the camel; and the value of this distinction has been exaggerated owing to the common conception of the ribs as special bones, distinct from the vertebræ, and their non-recognition as parts of a vertebra equivalent to the neurapophyses and other autogenous elements. The discovery of the pleurapophyses under the condition of rudimental ribs attached to the ends of the lumbar diapophyses, which afterwards become suturally attached or anchylosed, and the pleurapophysial nature of a part of the so-called perforated transverse process of the cervical vertebra, show that the anthropotomical definition of a dorsal vertebra, as one that supports ribs, is inapplicable to the mammalia generally, and is essentially incorrect. It is convenient, in comparative tables of vertebral formulæ, to denote the number of those vertebræ of the trunk in which the pleurapophyses remain free and moveable, constituting the "ribs" of anthropotomy; but the differences sometimes occurring in this respect, in individuals of the same species, have their unimportance manifested when the true nature of a rib is recognised. The vertebral formulæ of the artiodactyle skeletons show that the difference in the number of the so-called dorsal and lumbar vertebræ does not affect the number of the entire dorso-lumbar series: thus the Indian wild boar has *d*, 13, *l*, 6, = 19; *i. e.*, 13 dorsal, and 6 lumbar, making a total of 19 trunk-vertebræ; the domestic hog and the peccari have *d*, 14, *l*, 5, = 19; the hippopotamus has *d*, 15, *l*, 4, = 19; the gnu and aurochs have *d*, 14, *l*, 5, = 19; the ox and most of the true ruminants have *d* 13, *l* 6, = 19; the camel and lamas have *d* 12, *l* 7, = 19. These facts illustrate the natural character and true affinities of the artiodactyle group. They are further shown by the absence of the third trochanter in the femur, and by the place of perforation of the medullary artery at the fore and upper part of the shaft, as in the hippopotamus, the hog, and most of the ruminants. The fore part of the astragalus is divided into two equal or subequal facets; the os magnum does not exceed, or is less than, the unciforme in size, in the carpus; and the ectocuneiforme is less, or not larger, than the cuboid, in the tarsus. The digit answering to the third in the pentadactyle foot is unsymmetrical, and forms, with that answering to the fourth, a symmetrical pair. If the species be horned, the horns form one pair or two pairs; they are never developed singly and symmetrically from the median line. The post-tympanic does not project downward distinctly from the mastoid, nor supersedes it in any artiodactyle; and the paroccipital always exceeds both in length. The bony palate extends further back than in the perissodactyles; the hinder aperture of the nasal passages is more vertical, and commences posterior to the last molar tooth. The base of the pterygoid process is not perforated by the ectocarotid artery. The crowns of the premolars are smaller and less complex than those of the true molars, usually representing half of such crown. The last milk-molar is trilobed.

To these osteological and dental characters may be added some important modifications of internal structure, as *e. g.* the complex form of the stomach in the hippopotamus, peccari, and ruminants, the comparatively small and simple cæcum, and the spirally folded colon, which equally indicate the mutual affinities of the even-toed or artiodactyle hoofed quadrupeds, and their claims to be regarded as a natural group of the Ungulata. Many extinct genera, *e. g.* chæropotamus, anthracotherium, hyopotamus, dichodon, merycopotamus, xiphodon, dichobune, anoplotherium, have been discovered, which once linked together the now broken series of Artiodactyla, represented by the existing genera hippopotamus, sus, dicotyles, camelus, moschus, camelopardalis, cervus, antilope, ovis, and bos.

As we have now traced both the fore and hind foot to the five-toed or pentadactyle structure, with the definite number of joints or phalanges in each toe, characteristic of the highest class of vertebrate animals, a few remarks will be offered in illustration of the plan of structure which prevails in such extremities, and of the law that governs the departure from the pentadactyle type in the mammalia.

The essential nature of the limbs is best illustrated by the fish called protopterus, and by some of the lower reptiles that retain gills with lungs.

Fig. 32.



PROTOPTERUS.

If the segment of the skeleton supporting the rudiments of the fore-limbs in the protopterus (Fig. 32), be compared with the modification of the typical vertebra, exemplified in Fig. 5, p. 169, it will be seen to be constructed on the same type. The hæmal arch is most expanded, and it is composed of a pleurapophysis or vertebral rib, *pl*, and a hæmapophysis or sternal rib, *h*, on each side; the hæmal spine, or sternum, is not here developed; the long, many-jointed ray, *a*, answers to the more simple diverging appendage, *a*, in Fig. 5.

The segment supporting these appendages, or first rudiments of the fore-limb in the fish, is the occipital one, or the last vertebra of the skull. The pleurapophysis of this segment is the seat of all those modifications which have earned for it the special name of "scapula," 51; the hæmapophysis is the seat of those that have led to its being called "coracoid," 52.

The corresponding segment of the batrachian amphiuma (Fig. 33) yields the next important modification of these parts. The scapulæ, *pl*, 51, are detached from the occiput, or neural arch; the coracoids, *h*, 52, are much expanded; three segments of the diverging appendage, *a*, are ossified, and two of these segments are bifid, showing the beginning of the radiating multiplication of its parts. The first segment is the seat of those modifications which have obtained for it the special name of "humerus," 53; the two divisions of the next segment of the appendage are called "ulna," 53, and "radius," 54; the remainder of the limb is called "manus," or hand; 56 is the gristly carpus, and the two bony divisions are the digits or fingers, 57.

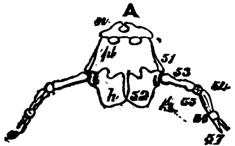
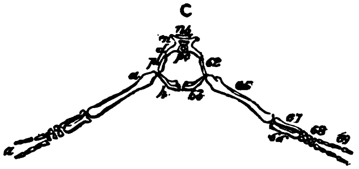


Fig. 33. AMPHIUMA.

The segment supporting the hind-limbs retains most of its typical character in the subterranean reptile called the Proteus; one sees, *e. g.*, in Fig. 34, that the centrum has coalesced with the neurapophyses, *n*, and neural spine, *ns*, forming the neural arch from which the diapophyses, *d*, are developed: the more expanded hæmal arch consists of the pleurapophyses, *pl*, and the hæmapophyses, *h;* the former is called the "ilium," 62, the latter the "ischium," 63; and, as the hæmapophyses of another segment are usually added to the scapular arch, when they receive the name of "clavicles," so also the hæmapophyses of a contiguous segment are usually added to the pelvic arch, when they are called "pubic bones."

Fig. 34.

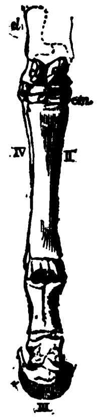


PROTEUS.

The pelvic diverging appendage, *a a*, has advanced to the same stage of complexity in the proteus, as the scapular one in the amphiuma; the first ossified segment is called "femur," 65; the divisions of the next segment are respectively termed "tibia," 66, and "fibula," 67; the first set of short bones in the "pes," or foot, are called "tarsals," 68; those of the two toes are called "metatarsals" and "phalanges," 69.

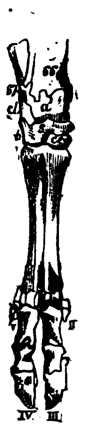
The tarsal bones, from the degree of constancy of their forms and relative positions have received distinct names. In Fig. 35 of the bones of the hind foot in the horse, *a* marks the "astragalus," *cl*, the "calcaneum," or heel-bone, the prominent part of which forms the "hock;" *s* is the "scaphoides," or naviculare, *b*, the "cuboid," *ce*, "ectocuneiform," and *cm*, the "mesocuneiform." Now, the ectocuneiform in all mammalia supports the third or middle

Fig. 35.



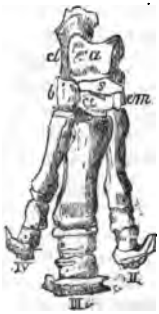
HORSE.

Fig. 36.



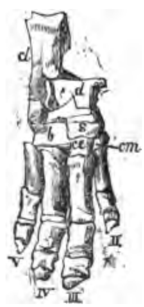
OX.

Fig. 37.



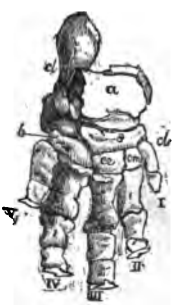
RHINOCEROS.

Fig. 38.



HIPPOPOTAMUS.

Fig. 39.



ELEPHANT.

of the five toes when they are all present, the mesocuneiform supports the second toe, and the cuboides the fourth and fifth. We see, therefore, in the horse, that the very large bone articulated to the ectocuneiform, *ce*, is the metatarsal of the *third* toe, to which are articulated the three phalanges of the same toe, *iii*, the last phalanx being expanded to sustain the hoof. The small bone called "splint-bone," by veterinarians, articulated to the "mesocuneiform," is the stunted metatarsal of the *second* toe, *ii;* the outer "splint-bone," articulated to the "cuboides," is the similarly stunted metatarsal of the *fourth* toe, *iv*.

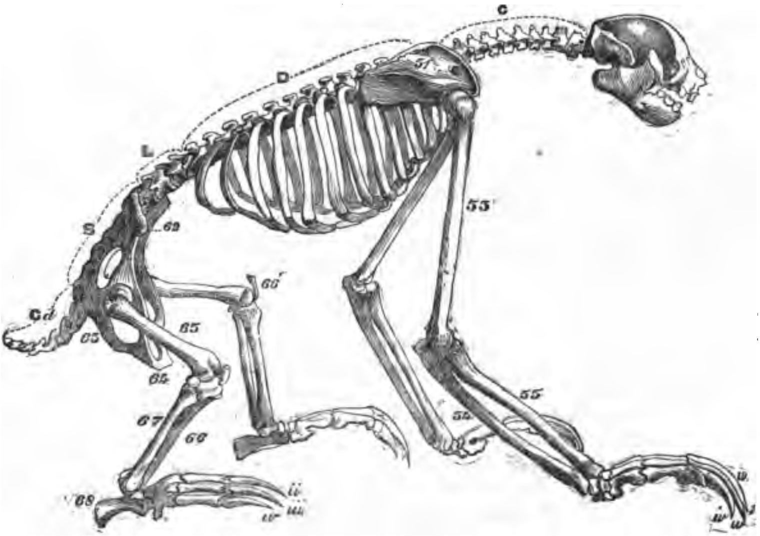
In the foot of the ox (Fig. 36), the cuboides, *b*, presents a marked increase of size, equalling the ectocuneiform, *ce*, which is proportionally diminished. The single bone, called "cannon-bone," which articulates with both these carpal bones, does not answer to the single "cannon-bone" in the horse, but to the metatarsals of both the *third* and the *fourth* digits; it is accordingly found to consist of those two distinct bones in the fœtal ruminant, and there are a few species in which that distinction is retained. Marks of the primitive division are always perceptible, especially at its lower end, where there are two distinct joints or condyles, for the phalanges of the third, *iii*, and fourth, *iv*, toes. In the horse the rudiments of the two stunted toes were their upper ends or metatarsal bones; in the ox they consist of their lower ends or phalanges; these form the "spurious hoofs," and are parts of the second, *ii*, and fifth, *v*, toes (Fig. 36). The rhinoceros more closely resembles the horse in the bony structure of its hind foot (Fig. 37); the ectocuneiform is still the largest of the three lowest tarsal bones, although the mesocuneiform, *cm*, and the cuboids, *b*, have gained increased dimensions in accordance with the completely developed toes which they support; these toes we therefore recognise as being answerable to the rudiments of the second, *ii*, and fourth, *iv*, in the horse, the principal toe being still the third, *iii*. The hippopotamus (Fig. 38) chiefly differs from the ox, as the rhinoceros differs from the horse, viz., by manifesting the two toes fully developed, which were rudimental in the more simple foot; the cuboides, *b*, being proportionally extended to support the fifth toe, *v*, as well as the fourth, *iv;* the second toe, *ii*, articulates, as usual, with a distinct tarsal bone. In the elephant (Fig. 39), where a fifth digit is added, answering to our first or great toe, I, there is also a distinct carpal bone, called the "entocuneiform," *ci*, and the tarsus presents, as in other pentadactyle mammals, all the bones which are seen in the human tarsus, viz., the astragalus, *a*, the calcaneum, *c*, the scaphoides, *s*, the entocuneiform, *ci*, the mesocuneiform, *cm*, the ectocuneiform, *ce*, and the cuboides, *b*.

The course of the simplification of the pentadactyle foot or hand is first a diminution and removal of the innermost digit, *i;* next of the outermost, *v;* then of the second, *ii;* and lastly of the fourth, *iv;* the third or middle toe, *iii*, being the most constant and important of the five toes. The same law or progress of simplification prevails in the fore-foot or hand. The thumb is the first to disappear, then the little finger, and the middle finger is the most constant, and forms the single-hoofed fore-foot of the horse.

The scapula, 51, in the fore-limb repeats or answers to the ilium, 62, in the hind limb; the coracoid, 52, to the ischium, 63; the clavicle, 58, to the pubis, 64; the humerus, 53, to the femur, 65; the radius, 55, to the tibia, 66; the ulna, 54, to the fibula, 67; the carpus, 56, repeats the tarsus, 68; and the metacarpus and phalanges of the fore-foot repeat the metatarsus and phalanges of the hind foot; they are technically called "serial homologues," or "homotypes," and each bone in the carpus can be shown to have its homotype in the tarsus.—See "Archetype of the Vertebrate Skeleton," p. 167.

Skeleton of the Sloth.—The transition from the quadrupeds with hoofs to those with claws seems in the present series to be abrupt; but it was made gradual by a group of animals, now extinct, which combined hoofs and claws in the same foot. Some of the outer toes, at least, were stunted and buried in a thick callosity, for the ordinary purpose of walking, whilst the other toes were provided with very long and strong claws for uprooting or tearing off the branches of trees. These singular beasts were of great bulk, and appear to have been peculiar to America. As restored by anatomical science, they have received the names of *Megatherium*, *Megalonyx*, *Mylodon*, &c. They were huge terrestrial sloths; the present remnants of the family consist of very few species enabled by their restricted bulk to climb the trees in quest of their leafy food, and peculiarly organized for arboreal life. The toes, which were modified in their huge predecessors, to tread the ground, are reduced to rudiments, or are undeveloped; and those only are retained which support the claws, now rendered by their length and curvature admirable instruments for clinging to the branches. The whole structure of the hind and fore limbs is modified to give full effect to these instruments as movers and suspenders of the body in the bosky retreats for which the sloths are destined; and, in the same degree, the power of the limbs to support and carry the animal along the bare ground is abrogated. Accordingly, when a sloth is placed on level ground, it presents the aspect of the most helpless and crippled of creatures. It is less able to raise its trunk above its limbs than the seal, and can only progress by availing itself of some inequality in the soil offering a holdfast to its claws, and enabling it to drag itself along. But to judge of the creative dispensations towards such an animal by observation of it, or reports of its procedure, under these unnatural circumstances,

Fig. 40.



SKELETON OF THE SLOTH.

would be as reasonable as a speculation on the natural powers of a tailor suddenly transferred from his shop-board to the rigging of a ship under weigh, or of a thorough-bred seaman mounted for the first time on a full-blood horse at Ascot. Rouse the prostrate sloth, and let it hook on to the lower bough of a tree, and the comparative agility with which it mounts to the topmost branches will surprise the spectator. In its native South American woods its agility is still more remarkable, when the trees are agitated by a storm. At that time the instinct of the sloth teaches it that the migration from tree to tree will be most facilitated. Swinging to and fro, back downwards, as is its habitual position, at the end of a branch just strong enough to support the animal, it takes advantage of the first branch of the adjoining tree that may be swayed by the blast within its reach, and stretching out its fore-limb, it hooks itself on, and at once transfers itself to what is equivalent to a fresh pasture. The story of the sloth voluntarily dropping to the ground, and crawling under pressure of starvation to another tree, is one of the fabulous excrescences of a credulous and gossipping zoology.

In the sloth, accordingly (Fig. 40), the fore-limbs are much elongated, and that less at the expense of the hand than of the arm and fore-arm. The humerus, 53, is of unwonted length—is slender and straight; the radius, 55, and ulna, 54, are of similar proportions—the former straight, the latter so bent as to leave a wide interosseous space. Now, moreover, these bones, instead of being firmly united as one bone, are so articulated with each other as to permit a reciprocal rotatory movement, chiefly performed, however, by the radius; and since to this bone the carpal segment of the hand is mainly articulated, that prehensile member can be turned prone or supine, as in the human arm and hand. Six bones are preserved in the carpus of three-toed sloth (*Bradypus tridactylus*), answering to those called "lunare," "cuneiforme," "unciforme," and "pisiforme," also to the "scaphoides and trapezium" united, and to the "trapezoides and magnum" united. The scapho-trapezium is characteristic of the sloth-tribe, and is found in the extinct as well as existing species. The articulation of the carpus with the radius, and with the metacarpus, is such as to turn the palm of the long hand inwards, and bring its outer edge to the ground. The three fully-developed metacarpals are confluent at their base, which is also anchylosed to the rudiments of the first and fifth metacarpals; the proximal phalanges of the digits answering to *ii*, *iii*, and *iv*, are confluent with their metacarpals, and those digits appear therefore to have only two joints. The last phalanx is remarkably modified for the attachment of the very long and strong claw.

With regard to the blade-bone of the sloth, 51, it is much broader in proportion to its length than in the swift cloven-footed herbivores; the spinous process is unusually short; the acromion is of moderate length, and unexpanded at its extremity; the supraspinal fossa is the broadest, and has a perforation instead of the usual "supraspinal" notch. There is a short clavicular bone attached to the acromion, but not attaining to the sternum.

The iliac bones, 62, repeat the modifications of their homotypes the scapulæ, and are of unusual breadth as compared with those of other quadrupeds; they soon become anchylosed to the broad sacrum, S; the ischia, 63, and pubes, 64, are long and slender, and circumscribe unusually large "thyroid" and "ischial" foramina, the latter being completed by the coalescence of the tuberosities of the ischia with the transverse processes of the last two sacral vertebræ. The head of the femur, 65, has no impression of a ligamentum teres. The patella, 66′, is ossified; there is a fabella behind the external condyle. The tibia, 66, and fibula, 67, are bent in opposite directions, intercepting a very wide interosseous space. The anchylosis of their two extremities, which has been found in older specimens, has not taken place here. The inner malleolus projects backwards and supports a grooved process. The outer malleolus projects downwards, and fits like a pivot into a socket in the astragalus, turning the sole of the foot inwards—a position like that of the hand—best adapted for grasping boughs. The calcaneum, 68, is remarkably long and compressed. The scaphoid, cuboid, and cuneiform bones have become confluent with each other and the metatarsals, of which the first and fifth exist only in rudiment. The other three have likewise coalesced with the proximal phalanges of the toes which they support: these toes answer to the second, third, and fourth, in the human foot.

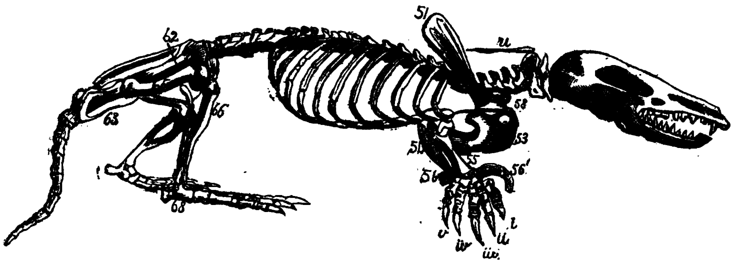
The short and small head of the sloth is supported on a long and flexible neck presenting the very unusual character in the Mammalian class of nine vertebræ, C—the superadded two, however, appearing to have been impressed from the dorsal series D by their short, pointed, and usually moveable ribs. The head and mouth can be turned round every part of a branch in quest of the leafy food by this mechanism of the neck. As the trunk is commonly suspended from the limbs with the back downwards, the muscles destined for the movements of the back and support of the head are feebly developed, and the vertebral processes for their attachment are proportionally short. The spines of the neck-vertebræ are of more equal length than in most mammals—that of the dentata being little larger than the rest: the spines gradually subside in the posterior dorsals, and become obsolete in the lumbar vertebræ. The first pair of fully-developed ribs, marking the beginning of the true "dorsal" series of vertebræ, are anchylosed to the breast-bone, which consists of eight ossicles. In the two-toed sloth, however, which has twenty-three dorsal vertebræ, there are as many as seventeen subcubical sternal bones in one long row, with their angles truncated for the terminal articulations of the sternal ribs, which are ossified.

The skull of the sloth is chiefly remarkable for the size, shape, and connections of the malar bone, which is freely suspended by its anterior attachment to the maxillary and frontal, and bifurcates behind; one division extending downwards, outside the lower jaw, the other ascending above the free termination of the zygomatic process of the squamosal. The premaxillary bone is single and edentulous, being represented only by its palatal portion completing the maxillary arch, but not sending any processes upwards to the nasals.

The skull in the toothless ant-eater chiefly forms a long, slender, slightly-bent bony sheath for its still longer and more slender tongue, the main instrument for obtaining its insect food. The mouth in the living animal is a small orifice at the end of the tubular muzzle, just big enough to let the vermiform tongue glide easily in and out. The fore-limbs are remarkable for the great size and strength of the claw developed from the middle digit: this is the instrument by which the ant-eater mainly effects the breach in the walls of the termite fortresses, which it habitually besieges in order to prey upon their inhabitants and constructors. As in the sloths, both fore and hind feet have an inclination inwards, whereby the sharp ends of the long claws are prevented from being worn by that constant application to the ground which must have resulted from the ordinary position of the foot. The trunk-vertebræ of the ant-eater are chiefly remarkable for the number of accessory joints by which they are articulated together. This complex structure is also met with in the armadillos, in which the anterior zygapophyses of the dorsal vertebræ send processes—the metapophyses (Fig. 2, p. 165), *m*, *m*—upwards, outwards, and forwards, which processes, progressively increasing in the hinder vertebræ, attain, in the lumbar region, a length equal to that of the spinous processes, *ns*, and have the same relation to them, in the support of the osseous carapace, as the "tie-bearers" have to the "king-post" in the architecture of a roof.

Skeleton of the Mole.—The mole is hardly less fitted for the actions of an ordinary land-quadruped than the sloth; but the one is as admirably constructed for subterraneous as the other for arboreal life. The fore-limbs are as remarkably short, broad, and massive in the mole, as they are long and slender in the sloth; yet the same osseous elements, similarly disposed, occur in the skeleton of each. The head of the mole is long and cone-shaped; its broad base joins on the trunk without any outward appearance of a neck. The fore-part of the trunk, to which the principal muscular masses working the fore-limbs are attached, is the thickest, and thence the body tapers to the hind-quarters, which are supported by limbs as slender as they are short.

Fig. 41.



SKELETON OF THE MOLE.

The neck-bones, nevertheless, are not wanting; they even exist in the same number as in the giraffe; the vertebral formula of the mole being—7 cervical, 13 dorsal, 6 lumbar, 5 sacral, and 10 caudal. The spine of the second vertebra or dentata is large, and extended back over the third vertebra: the neural arches of this and the succeeding neck-vertebræ form thin simple arches without spines: the entire vertebræ have been described as mere rings of bone; but the transverse processes of the fourth, fifth, and sixth cervicals are produced forwards and backwards, and overlap each other: in the seventh vertebra those processes are reduced to tubercular diapophyses which are not perforated: the bodies of the vertebræ are depressed and quadrate. The part answering to the nuchal ligament in the giraffe is bony in the mole, *u*.

The first sternal bone, or manubrium, is of unusual length, being much produced forwards, and its under surface downwards in the shape of a deep keel for extending the origin of the pectoral muscles. Seven pairs of ribs directly join the sternum, which consists of four bones, in addition to the manubrium and an ossified ensiform appendage. The neural spines, which are almost obsolete in the first eight dorsals, rapidly gain length in the rest, and are antroverted in the last two dorsal vertebræ. The diapophyses, being developed in the posterior dorsals, determine the nature of the longer homologous processes in the lumbar vertebræ.

The lumbar spines are low, but of considerable antero-posterior extent: the diapophyses are bent forward in the last four vertebræ: a small, detached, wedge-shaped hypapophysis is fixed into the lower interspace of the bodies of the lumbar vertebræ.

The scapula, 51, is very long and narrow, but thick, and almost three-sided: the common rib-shape is resumed in this cranial pleurapophysis, as we have seen in the bird and tortoise. The clavicle, on the other hand, instead of the usual long and slender figure, presents the form of a cube, being very short and broad, articulated firmly to the anteriorly projecting breast-bone, and more loosely with the acromion and head of the humerus.

This bone, 53, would be classified amongst the "flat" bones. It is almost as broad as it is long, especially at its proximal end, which presents two articular surfaces—one for the scapula, the other for the clavicle: the expanse of the bone beyond these surfaces relates to the formation of an adequate extent of attachment for the deltoid, pectoral, and other great burrowing muscles. All the other bones of the fore-limb are as extremely modified for fossorial actions. The olecranon expands transversely at its extremity, and the back part of the ulna is produced into a strong ridge of bone.

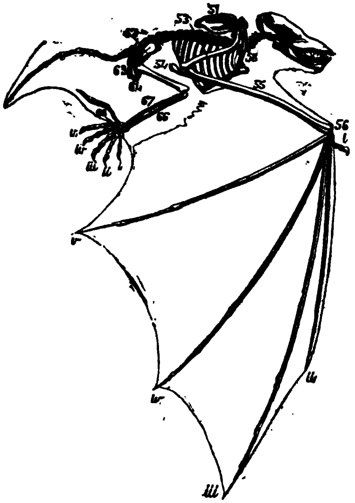
The shaft of the radius is divided by a wide interosseous space from the ulna, and the head of the radius is produced into a hook-shaped process like a second "olecranon." The carpal series consists of five bones in each row—the scaphoid being divided in the first, and a sesamoid being added to the second row; moreover, there is a large supplementary sickle-shaped bone, extending from the radius to the metacarpal of the pollex, giving increased breadth and a convex margin to the radial side of the very powerful hand, and chiefly completing its adaptation to the act of rapidly displacing the soil. The phalanges of the fingers are short and very strong: the last are bifid at their ends for a firmer attachment of the strong claws. Little more of the hand than these claws, and the digging or scraping edge, projects beyond the sheath of skin enveloping the other joints, and connecting the hand with the trunk.

The common position of the arm-bone is with its distal end most raised. The fore-arm, with the elbow raised, is in the state between pronation and supination, the radial side of the hand being downwards, and the palm directed outwards. The whole limb, in its position and structure, is unequalled in the vertebrate series as a fossorial instrument, and only paralleled by the corresponding limb in the mole-cricket (*Gryllotalpa*) amongst the insect-tribes.

No impediment is offered by the hinder parts of the body or limbs when the thickest part of the animated wedge has worked its way through the soil. The pelvis is remarkably narrow. The ossa innominata have coalesced with the sacrum but not with each other, the pubic arch remaining open. The bodies of the sacral vertebræ are blended together, and are carinate below; their neural spines have coalesced to form a high ridge. The acetabula look almost directly outwards. The head of the femur has no pit for a round ligament. A fabella is preserved behind the outer condyle. A hamular process is sent off from the head of the tibia and fibula; the lower moieties of the shafts of these bones are blended together. The toes are five in number on the hind-feet as in the fore, but are much more feebly developed. They serve to throw back the loose earth detached by the spade-shaped hands.

Skeleton of the Bat.—The form of limb presented by the arm and hand of the bat offers the most striking contrast to the burrowing trowel of the mole. Viewed in the living animal it is a thin, widely-expanded sheet of membrane, sustained like an umbrella by slender rays, and flapped by means of these up and down in the air, and with such force and rapidity, as, combined with its extensive surface, to react upon the rare element more powerfully than gravitation can attract the weight to which the fore-limbs are attached; consequently the body is raised aloft, and borne swiftly through the air. The mammal now rivals the bird in its faculty of progressive motion; it flies, and the instruments of its aërial course are called "wings." The whole frame of the bat is in harmony with this faculty, but the mamalian type of skeleton is in nowise departed from.

Fig. 42.



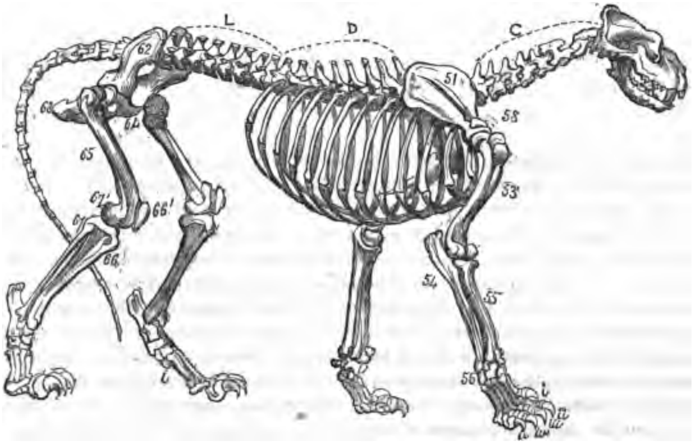
SKELETON OF THE BAT (*Vespertilio murinus*).

The vertebral formula of the common bat (*Vespertilio murinus*) (Fig. 42), is—7 cervical, 12 dorsal, 7 lumbar, 3 sacral, and 8 caudal vertebræ. The chief characteristics of the skeleton are—the gradual diminution of size of the spinal column from the cervical to the sacral regions; the absence of neural spines in the vertebræ beyond the dentata; a keeled sternum; long and strong, bent clavicles, 58; broad scapulæ, 51; elongated humeri, 53; more elongated and slender radius, 55; and still longer and more slender metacarpals and phalanges of the four fingers, *ii*, *iii*, *iv*, *v*, which are without claws, the thumb, *i*, being short and provided with a claw: the pelvis, 62, is small, slender, and open at the pubis, 63; the fibula, 67, is rudimental, like the ulna, 54, in the fore-arm. The common bat has a long and slender stiliform appendage to the heel, 68, which helps to sustain the caudo-femoral membrane. The hind digits are five in number, short, subequal, each provided with a claw; they are the instruments by which the bat suspends itself, head downwards, during its daily summer sleep, and continued winter torpor.

Skeleton of the Carnivorous Mammalia.—The lion may be regarded as the type of a quadruped. The well-adjusted proportions of the head, the trunk, the fore-limbs, and tail concur with their structure to form an animal swift in course, agile in leaps and bounds, terrible in the overpowering force of the blows inflicted by the fore-limbs. The strong, sharp, much-curved, retractile talons terminating the broad powerful feet, enable the carnivore to seize the prey it has overtaken, and to rend the body it has struck down. The jaws have a proportional strength, and are armed with fangs fitted to pierce, lacerate, and kill.

The carnivorous character of the skull, as exemplified by the sagittal and occipita crests, by the strength and expanse of the zygomatic arches, by the breadth, depth, and shortness of the jaws, by the height of the coronoid processes, and by the depth and extent of the fossæ of the lower jaw for the attachment of the biting muscles, reaches its maximum in the lion. The triangular occipital region is remarkable for the depth and boldness of the sculpturing of its outer surface, indicative of the powerful muscles working the whole skull upon the neck and trunk. The conjoined paroccipitals and mastoids form a broad and thick capsular support for the back part of the acoustic bullæ. The pterygoid processes are imperforate. A well-marked groove extends on each side of the bony palate from the posterior to the anterior palatine foramina. The premaxillaries are comparatively short, and one-half of the lateral border of the nasals directly articulates with the maxillaries. The antorbital foramina are largely indicative of the size of the sensitive nerve supplying the well-developed whiskers. Within the cranium we find that ossification has extended into the membrane dividing the cerebrum from the cerebellum. This bony tentorium extends above the petrosal to the ridge overhanging the Gasserian fossa; the petrosal is short, its apex is neither notched nor perforated; the cerebellar pit is very shallow. The sella turcica is deep, and well defined by both the anterior and posterior clinoids. The rhinencephalic fossa is relatively larger in the lion than in most carnivora, and is defined by a well-marked angle of the inner table of the skull from the prosencephalic compartment. The olfactory chamber extends backwards both above and below the rhinencephalic fossa; the upper part of the chamber is divided into two sinuses on each side. The superior turbinals extend into the anterior sinus, and below into the presphenoidal sinus. All the bones of the skeleton are remarkable for their whiteness and compact structure.

Fig. 43.



SKELETON OF THE LION (*Felis leo*).

The vertebral formula of the lion (Fig. 43) is—7 cervical, 13 dorsal, 7 lumbar, 3 sacral, and 23 caudal. The last cervical vertebra has the transverse processes imperforate, being formed only by diapophyses. The eleventh dorsal is that toward which the spines of the other trunk-vertebræ converge, and indicates the centre of motion of the trunk in this bounding quadruped. Eight pairs of ribs directly join the sternum, which consists of eight bones. The clavicles are reduced to clavicular bones, 58, suspended in the flesh. The supraspinal fossa of the scapula is less deep than the infraspinal one, and its border is almost uniformly convex; the acromion is bifid, the recurved point being little larger than the extremity or anterior point. The humerus, 53, is perforated above the inner condyle, but not between the condyles. The radius, 55, and ulna, 54, are so articulated as to permit a free rotation of the forepaw. The scaphoid and lunar bones are connate. Besides these, the bones of the carpus are the cuneiforme; the pisiforme; the trapezium, which gives an articulation to the ulnar side of the base of the short metacarpus of the pollex; the trapezoides; the magnum, which is the least of the carpal bones; the unciforme, which supports, as usual, the metacarpals of the fourth and fifth digits; and the pisiforme, which projects far backwards, like a small calcaneum: there is also a supplementary oscicle wedged in the interspace between the prominent end of the scapho-lunar bone and the proximal end of the metacarpal of the pollex. The pollex is retained on the fore-foot, and, like the other toes, is terminated by a large, compressed, retractile, ungual phalanx, forming a deep sheath, for the firm attachment of the large curved and sharp-pointed claws.

The pelvis, 62, 63, 64, the femur, 65, the tibia, 66, and fibula, 67, offer no remarkable modifications of structure; the patella, 66, is well ossified, and there is a fabella, 67, behind each condyle of the femur. The tarsal bones are the astragalus; the scaphoides; the calcaneum; the cuboides, which, like the unciforme in the carpus, supports the two outer digits; the cuneiforme externum, which, like the magnum, supports the middle digit; the cuneiforme medium, which, like the trapezoides, supports the second digit; and the cuneiforme internum, which supports the rudiment of the metatarsal of the first or innermost digit.

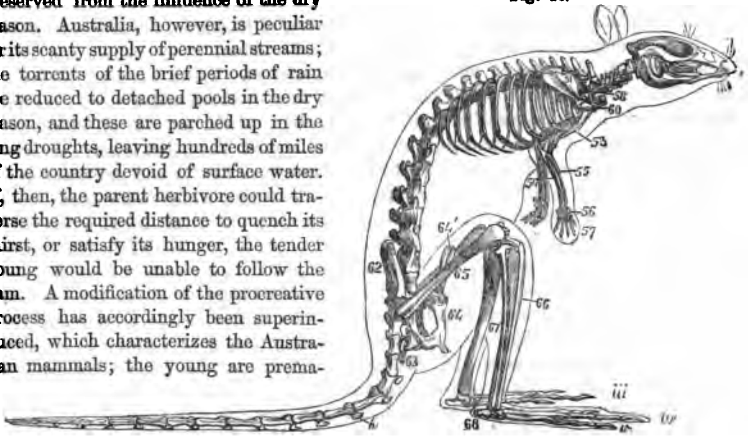
The last or ungual phalanx, in both fore and hind feet, has a bony sheath at its base for the firmer implantation of the claw; and its joint is at the back part of the proximal end of the phalanx, whereby it can be drawn upwards upon the second phalanx, when the claw becomes concealed in the fold of integument forming the interspace of the digits.

This state of retraction is constantly maintained, except when overcome by an extending force, by means of elastic ligaments. The principal one arises from the outer side and distal extremity of the second phalanx, and is inserted into the superior angle of the last phalanx; a second arises from the outer side and proximal end of the second phalanx, and passes obliquely to be inserted at the inner side of the base of the last phalanx. A third, which arises from the inner side and proximal extremity of the second phalanx, is inserted at the same point as the preceding. The tendon of the flexor profundus perforans is the antagonist of the elastic ligaments. By the action of that muscle the last phalanx is drawn forwards and downwards, and the claw exposed. In order to produce the full effect of drawing out the claw, a corresponding action of the extensor muscle is necessary, to support and fix the second phalanx; by its ultimate insertion in the terminal phalanx, it serves also to restrain and regulate the actions of the flexor muscle. As the phalanges of the hind-foot are retracted in a different direction to those of the fore-foot, *i. e.* directly upon, and not by the side of the second phalanx, the elastic ligaments are differently disposed, but perform the same main office.

It seems scarcely necessary to allude to the final intention of these beautiful structures, which are, with some slight modifications, common to the genus *Felis*. The claws being thus retracted within folds of the integument, are preserved constantly sharp, and ready for their destined functions, not being blunted and worn away in the ordinary progressive motions of the animal; while at the same time the sole of the foot, being padded, such soft parts only are brought in contact with the ground as conduce to the noiseless tread of the stealthy feline tribe. This highly-developed unguiculate structure with the dental system and concomitant modifications of the skull, completes the predatory character of the typical *Carnivora*.

Skeleton of the Kangaroo.—Australia possesses an indigenous race of herbivorous mammals created to enjoy existence on its grassy plains. But the climate of this fifth continent, as, from its extent, it has been termed, is subject to droughts of unusual duration, and the parched up grass, ignited by the electric bolt or other cause, often raises a conflagration of fearful extent, and leaves a correspondingly wide-spread blackened desert. To the antelope, and other ruminants of tropical or warmer latitudes, swiftness of limb has been given, which enables them to migrate to river valleys, where the vegetation is preserved from the influence of the dry season. Australia, however, is peculiar for its scanty supply of perennial streams; the torrents of the brief periods of rain are reduced to detached pools in the dry season, and these are parched up in the long droughts, leaving hundreds of miles of the country devoid of surface water. If, then, the parent herbivore could traverse the required distance to quench its thirst, or satisfy its hunger, the tender young would be unable to follow the dam. A modification of the procreative process has accordingly been superinduced, which characterizes the Australian mammals; the young are prematurely brought forth of embryonic size and helplessness, and are transferred to a pouch of inverted skin, concealing the udder; and in this marsupium, as in a well-stored vehicle, they are easily transferred by the parent to any distance to which the climatal conditions may compel her to migrate. The economy of this portable nursery, the requisite manipulation of the suckling young therein suspended from the teat, demand a certain prehensile power of the fore-limbs, a freedom of the digits, with some opposable faculty in them, and the possession of so much sense of touch as would be impossible were the digit to be incased in a hoof; the horny matter is accordingly developed only on the upper surface of the finger-end, and is in the form of a claw. But the unguiculate pentadactyle extremity—though a higher grade of structure in the progress of limbs—is not suited for the exigencies of the herbivore, and would have appeared utterly incompatible with an existence dependent on grazing in wild pastures, had we argued from knowledge restricted to the forms and structures of the hoofed herbivores of the Europæo-Asiatic, African, and American continents. How, then, it may be asked, is this difficulty overcome in the case of a grazing animal, necessarily a marsupial, and consequently an unguiculate one? The answer need only be a reference to fig. 44: the requisite faculty of migration of the parent with the tender offspring is gained by transferring the locomotive power to the hinder pair of limbs extraordinarily developed, and aided by a correspondingly powerful tail; the fore-limbs being restricted in their development to the size requisite for the marsupial offices and other accessory uses.

Fig. 44.



SKELETON OF THE KANGAROO (*Macropus elegans*).

This is the condition or explanation of the seemingly anomalous form and proportions of the kangaroo,—so strange, indeed, that the experienced naturalists, Banks and Solander, may well be excused for surmising they had seen a huge bird when they first caught a glimpse of the kangaroo in the strange land which they, with Cook, discovered.

The rapid course of the kangaroo is by a succession of leaps, in which twenty to thirty yards are cleared at a bound; the herbivore, instead of a swift courser on four pretty equally developed hoofed extremities, is, in Australia, a leaping animal; and the saltatorial modification of the mammalian skeleton is here shown in that of one of the swiftest and most agile of the numerous species of kangaroo, the *Macropus elegans*.

In this kangaroo, 13 vertebræ are dorsal, 6 are lumbar, 2 are sacral, and 28 are caudal, the first fourteen of which have hæmapophyses. These elements coalesce at their distal ends, and form small hæmal arches; they overspan and protect from pressure the great blood-vessels of the tail, the powerful muscular fasciculi of which derive increased surface of attachment from these hæmal arches. The pelvis is long; the strong prismatic ilia, 52, and the ischia, 63, carry out the great flexors and extensors of the thigh to a distance from their point of insertion—the femur, which makes these muscles operate upon that lever at a most advantageous angle; the trunk, borne along in the violent leaps, needs to be unusually firmly bound to the pelvic basis of the chief moving powers. Accordingly, we find a pair of bones, 64′, extending forwards from the pubic symphysis, 64, along the ventral walls, giving increased bony origin to the unusually developed median abdominal muscles attaching the thorax to the pelvis; and these "marsupial bones," as they are called, have accessory functions relating to reproduction in both sexes of the marsupial quadrupeds. The femur, 65, is more than twice the length of the humerus: it is proportionally strong, with well-developed great and small "trochanters," and a "fabella" behind one or both condyles. The patella is unossified. The fibula, 67, is immoveably united to the lower half of the tibia. This bone, 66, is of unusual length and strength, and is firmly interlocked below with the trochlear astragalus. The heel-bone sends backwards a long lever-like process for the favourable insertion of the extensors of the foot. This member is of very unusual length. The innermost toe, or hallux, is absent; the second and third toes are extremely slender, inclosed as far as the ungual phalanx in a common fold of integument, and reduced to the function of cleansing the fur. The offices of support and progression are performed by the two outer toes, *iv* and *v*, and principally by the fourth, which is enormously developed, and terminated by a long, strong, three-sided, bayonet-shaped claw; these two toes are supported, as usual, by the os cuboides, which is correspondingly large, whilst the naviculare and the cuneiform bones are proportionally reduced in size. The bones of the fore-limb, though comparatively diminutive, present all the complexities of structure of the unguiculate limb. The clavicle, 58, connects the acromion with the sternum, and affords a fulcrum to the shoulder-joint. The humerus, articulating below with a radius and ulna which can rotate on each other, developes ridges above both inner and outer condyles for the extended origin of the muscles of pronation and supination. The brachial artery pierces the entocondyloid ridge. The carpal bones, answering to the scaphoid and lunar in the human wrist, are here confluent. The digits are five in number, enjoy free, independent movements, and are each terminated by a sharp-curved claw.

Skeleton of the Quadrumana.—The sloth is an exclusively arboreal animal; its diet is foliage; it has but to bring its mouth to the leafy food, and the lips and tongue serve to strip it from the branches. The extremities, as we have seen, serve mainly to climb and cling to branches, and occasionally to hook down a tempting twig within reach of the mouth. There is, however, another much more extensive and diversified order of arboreal mammals destined to subsist on the fruits and other more highly developed products of the vegetable kingdom than mere leaves. In the monkeys, baboons, and apes the extremities are endowed with prehensile faculties of a more perfect and varied character than in the sloths; and this additional power is gained by a full development of the digits in normal number, with free and independent movements, which in one of them—the first or innermost—are such as that it can be opposed to the rest, so that objects of various size can be grasped. This modification converts a foot into a hand; and, as the mammals in question have the opposable "thumb" on both fore and hind limbs, they are called "quadrumana," or four-handed. The rest of the limb manifests a corresponding complexity or perfection of structure; the trunk is adjusted to accord with the actions of such instruments, and the brain is developed in proportion with the power of executing so great a variety of actions and movements as the four-handed structure gives capacity for.

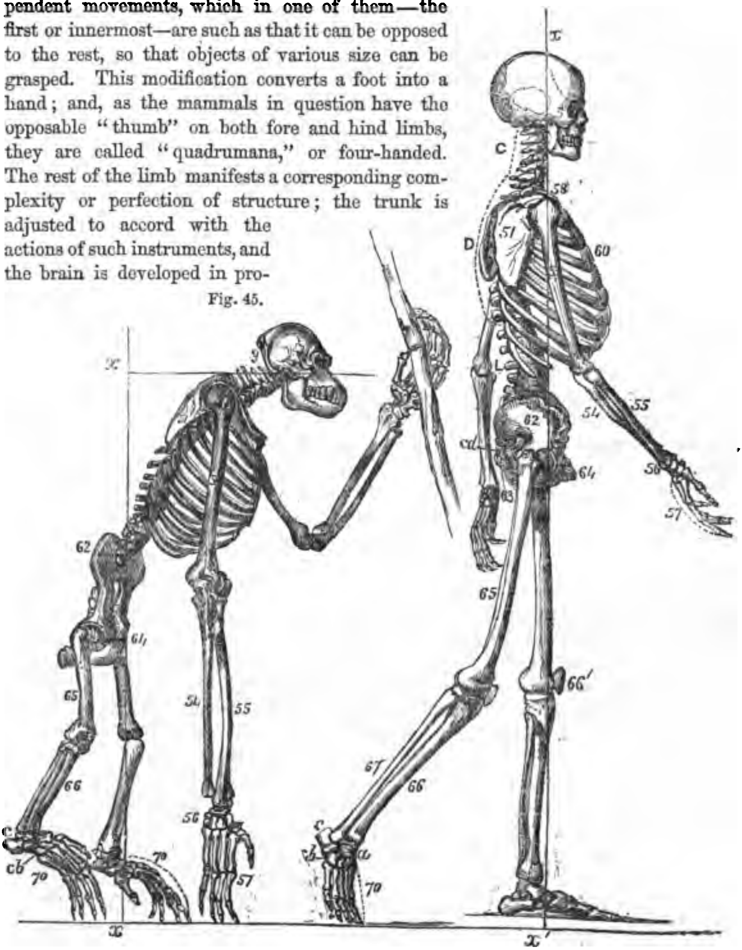


Fig. 45.

Fig. 46.

SKELETONS OF ORANG (*Pithecus satyrus*) AND MAN.

In the skull of the quadrumana are seen indications of a concomitant perfection of the outer senses: the orbits are entire, and directed forwards, with their outlets almost on the same plane; both eyes can thus be brought to bear upon the same object. The rest of the face, formed by the jaws, now begins to bear a smaller proportion to the progressively expanding cranium. The neck, of moderate length, has its seven vertebræ well developed, with the costal processes large in the fifth and sixth: the dorsal vertebræ, twelve, in the species figured (*Pithecus satyrus*), show by the convergence of their spines towards the vertical one on the ninth, that this is the centre of movement of the trunk. The lumbar vertebræ are four in number: in the inferior monkeys they are seven, and the anterior ones are firmly interlocked by well-developed anapophyses and metapophyses. The sacrum is still long and narrow. The tail, in some of the lower quadrumana, is of great length, including 30 vertebræ in the red monkey (*Cereopithecus ruber*), in which the anterior ones are complicated by having hæmal arches. The clavicles are entire in all quadrumana. The humerus has its tuberosities and condyloid crests well developed. The radius rotates freely on the ulna. The wrist has nine bones, owing to a division of the scaphoid, besides supplementary sesamoids adding to the force of some of the muscles of the hand; the thumb is proportionally shorter in the fore than in the hind foot. The patella is ossified, and in most baboons and monkeys there is a fabella behind each condyle of the femur. The fibula is entire, and articulated with the tibia at both ends. The tarsus has the same number and relative position of the bones as in man; but the heel-bone is shorter, and the whole foot rather more obliquely articulated upon the leg, the power of grasping being more cared for than that of supporting the body; the innermost toe forms a large and powerful opposable thumb.

There is a well-marked gradation in the quadrumanous series from the ordinary quadrupedal to the more bipedal type. In the lemurs and South American monkeys the anterior thumb is shorter and much less opposable than the hinder one; in the spider-monkeys it is wanting, and a compensation seems to be given by the remarkable prehensile faculty of the curved and callous extremity of the long tail. This member in the African and Asiatic monkeys is not prehensile, but the thumb of the fore-hand is opposable. In the true apes the tail is wanting, *i. e.* it is reduced to the rudiment called "os coccygis;" but the fore-arms are unusually developed in certain species, hence called "long-armed apes." These can swing themselves rapidly from bough to bough, traversing wide spaces in the aërial leap. The orang (Fig. 45) is also remarkable for the disproportionate length of the arms, but this difference from man becomes less in the chimpanzees. The large species called Gorilla, which of all brutes makes the nearest approach to man, is still strictly "quadrumanous;" the great toe, or "hallux,' being a grasping and opposable digit. But the hiatus that divides this highest of the ape tribe from the lowest of the human species is more strikingly and decisively manifested in the skull (Fig. 50). The common teeth in the male gorilla are developed, as in the male orang, to proportions emulating the tusks of the tiger; they are, however, weapons of combat and defence in these great apes, which are strictly frugivorous. Nevertheless, the muscles that have to work jaws so armed require modifications of the cranium akin to those that characterize the lion, viz., great interparietal, 7, and occipital, 3, cristæ and massive zygomatic arches. The spines of the cervical vertebræ are greatly elongated in relation to the support of such a skull, the facial part of which extends so far in advance of the joint between the head and neck. The chimpanzees, moreover, differ from man in having thirteen pairs of thoracic moveable ribs.

The long and flat iliac bones, 62, the short femora, 65, so articulated with the leg-bones, 66, as to retain habitually a bent position of the knee, the short calcanea, *c*, and the inward inclination of the sole of the foot, all indicate, in the highest as in the lowest quadrumana, an inaptitude for the erect position, and a compensating gain of climbing power favourable for a life to be spent in trees.

In the osteological structure of man (Fig. 46), the vertebrate archetype is furthest departed from by reason of the extreme modifications required to adjust it to the peculiar posture, locomotion, and endless variety of actions characteristic of the human race. As there is nothing, short of flight, done by the moving powers of other animals that serpents cannot do by the vertebral column alone, so there is no analogous action or mode of motion that man cannot perform, and mostly better, by his wonderfully developed limbs. The reports of the achievements of our athletes, prize wrestlers, prize pedestrians, funambulists, and the records of the shark-pursuing and shark-slaying amphibious Polynesians, of the equestrian people of the Pampas, of the Alpine chasers of the chamois, and of the scansorial bark-strippers of Aquitaine, concur in testifying to the intensity of those varied powers, when educed by habit and by skilled practice. The perfection of almost all modifications of active and motive structures seems to be attained in the human frame, but it is a perfection due to especial adaptation of the vertebrate type, with a proportional departure from its fundamental pattern. Let us see how this is exemplified in the skeleton of man (Fig. 46), viewing it from the foundation upwards.

In the typical mammalian foot the digits decrease from the middle to the two extremes of the series of five toes; and in the modifications of this type, as we have traced them through the several gradations (p. 243, Figs. 35-39), the innermost, *i*, is the first to disappear. In man it is the seat of excessive development, and receives the name of "hallux," or "great toe;" it retains however, its characteristic inferior number of phalanges. The tendons of a powerful muscle, which in the orang and chimpanzee are inserted into the three middle toes, are blended in man into one, and this is inserted into the hallux, upon which the force of the muscle now called "flexor longus pollicis" is exclusively concentrated.

The arrangement of other muscles, in subordination to the peculiar development of this toe, make it the chief fulcrum when the weight of the body is raised by the power acting upon the heel, the whole foot of man exemplifying the lever of the second kind. The strength and backward production of the heel-bone, *c*, relate to the augmentation of the power. The tarsal and metatarsal bones are coadjusted, so as to form arches both lengthwise and across, and receive the superincumbent weight from the tibia on the summit of a bony vault, which has the advantage of a certain elasticity combined with adequate strength. In proportion to the trunk, the pelvic limbs are longer than in any other animal; they even exceed those of the kangaroo, and are peculiar for the superior length of the femur, 65, and for the capacity of this bone to be brought, when the leg is extended, into the same line with the tibia, 66; the fibula, 67, is a distinct bone. The inner condyle of the femur is longer than the outer one, so that the shaft inclines a little outwards to its upper end, and joins a neck longer than in other animals, and set on at a very open angle. The weight of the body, received by the round heads of the thigh-bones, is thus transferred to a broader base, and its support in the upright posture facilitated. The pelvis is modified so as to receive and sustain better the abdominal viscera, and to give increased attachment to the muscles, especially the "glutei," which, comparatively small in other mammals, are in man vastly developed to balance the trunk upon the legs, and reciprocally to move these upon the trunk. The great breadth and anterior concavity of the ilium, 62, are characteristic modifications of this bone in man. The pelvis is more capacious, the tuberosity of the ischium is less prominent, and the symphysis pubis shorter, than in apes. The tail is reduced to three or four stunted vertebræ, anchylosed to form the bone called "os coccygis." The five vertebræ which coalesce to form the sacrum are of unusual breadth, and the free or "true" vertebræ, that rest on the base of the sacral wedge, gradually decrease in size to the upper part of the chest; all the free vertebræ, divided into five lumbar, twelve dorsal, and seven cervical, are so articulated as to describe three slight and graceful curves, the bend being forward in the loins, backward in the chest, and forward again in the neck. A soft elastic cushion, of "intervertebral" substance, rests between the bodies of the vertebræ. The distribution and libration of the trunk, with the superadded weight of the head and arms, are favoured by these gentle curves, and the shock in leaping is broken and diffused by the numerous elastic intervertebral joints. The expansion of the cranium behind, and the shortening of the face in front, give a globe-like form to the skull, which is poised by a pair of condyles, advanced to near the middle of its base upon the cups of the atlas; so that there is but a slight tendency to incline forwards when the balancing action of the muscles ceases, as when the head nods during sleep in an upright posture.

The framework of the upper extremity shows all the perfections that have been superinduced upon it in the mammalian series, viz., a complete clavicle, 58, antibrachial bones, 54, 55, with rotatory movements as well as those of flexion and extension, and the five digits, 57, free and endowed with great extent and variety of movements: of these, the innermost, which is the first to shrink and disappear in the lower mammalia, is in man the strongest, and is modified to form an opposable thumb more powerful and effective than in any of the quadrumana. The scapula, 51, presents an expanded surface of attachment for the muscles which work the arm in its free socket. the humerus, 53, exceeds in length the bones of the fore-arm. The carpal bones, 56, are eight in number, called scaphoides, lunare, cuneiforme, pisiforme, trapezium, trapezoides, magnum, and unciforme; of these the scaphoid and unciforme are compound bones; *i.e.* they consist each of two of the bones of the type-carpus, connate.

In the human skull, viewed in relation to the archetype, as exemplified in the fish and the crocodile, the following extreme modifications have been established. In the occipital segment the hæmal arch is detached and displaced, as in all vertebrates above fish; its pleurapophysis (scapula, 51) has exchanged the long and slender for the broad and flat form; the hæmapophysis (coracoid, 52) is rudimental, and coalesces with 51. The neurapophyses (exoccipitals, 2) coalesce with the neural spine (superoccipital), and next with the centrum (basioccipital). This afterwards coalesces with the centrum (basisphenoid) of the parietal segment. With this centrum also the neurapophyses, called "alisphenoids," and the centrum of the frontal vertebra, called "presphenoid," become anchylosed. The neural spine (parietal) retains its primitive distinctness, but is enormously expanded, and is bifid, in relation to the vast expansion of the brain in man. The parapophysis (mastoid) becomes confluent with the tympanic, petrosal, and squamosal, and with the pleurapophysis, called "stylohyal," of the hæmal (hyoidian) arch. The hæmapophysis is ligamentous, save at its junction with the hæmal spine when it forms the ossicle called "lesser cornu of the hyoid bone," the spine itself being the basihyal or body of the hyoid bone. The whole of this inverted arch is much reduced in size, its functions being limited to those of the tongue and larynx, in regard to taste, speech, and deglutition. The neurapophyses (orbitospenoids) becoming confluent with the centrum (presphenoid) of the frontal vertebra, and the latter coalescing with that of the parietal vertebra, the compound bone called "sphenoid" in anthropotomy results, which combines the centrums and neurapophyses of two cranial vertebræ, together with a diverging appendage (pterygoid) of the maxillary arch.

The knowledge of the essential nature of such a compound bone gives a clue to the phenomena of its development from so many separate points, which final causes could never have satisfactorily afforded. As the centrum, 5, becomes confluent with No. 1, a still more complex whole results, which has accordingly been described as a single bone, under the name of "os spheno-occipital" in some anthropotomies. Such a bone has not fewer than twelve distinct centres of ossification, corresponding with as many distinct bones in the cold-blooded animals that depart less from the vertebrate archetype. The spine of the frontal vertebra (frontal bone) is much expanded and bifid, like the parietal bone; but the two halves more frequently coalesce into a single bone, with which the parapophysis (postfrontal) is connate. The pleurapophysis of the hæmal arch (tympanic bone) is reduced to its function in relation to the organ of hearing, and becomes anchylosed to the petrosal, the squamosal, and the mastoid. The hæmapophysis is modified to form the dentigerous lower jaw, but articulates, as in other mammals, with a diverging appendage (squamosal) of the antecedent hæmal arch, now interposed between it and its proper pleurapophysis; the two hæmapophyses, moreover, become confluent at their distal ends, forming the symphysis mandibulæ.

The centrum of the first or nasal vertebra, like that of the last vertebra in birds, is shaped like a ploughshare, and is called "vomer:" the neurapophyses have been subject to similar compression, and are reduced to a pair of vertical plates, which coalesce together, and with parts of the olfactory capsules (upper and middle turbinals), forming the compound bone called "æthmoid;" of which the neurapophyses (prefrontals) form the "lamina perpendicularis" in human anatomy. The prefrontals assume this confluence and concealed position even in some fishes—*xiphias*, *e.g.*—and repeat the character in all mammalia and in most birds; but they become partially exposed in the ostrich and the batrachia. The spine of the nasal vertebra (nasal bones) is usually bifid, like those of the two succeeding segments; but it is much less expanded. The hæmal, called "maxillary" arch, is formed by the pleurapophyses (palatines) and by the hæmapophyses (maxillaries), with which the halves of the bifid hæmal spine (premaxillaries) are partly connate, and become completely confluent. Each moiety, or premaxillary, is reduced to the size required for the lodgment of two vertical incisors: as the canines in man do not exceed the adjoining teeth in length, and the premolars are reduced to two in number, the alveolar extent of the maxillary is short, and the whole upper jaw is very slightly prominent.

Of the diverging appendages of the maxillary arch, the more constant one, called "pterygoid," articulates with the palatine, but coalesces with the sphenoid; the second pair, formed by the malar, 26, and squamosal, 27, has been subject to a greater degree of modification; it still performs the function assigned to it in lizards and birds, where it has its typical ray-like figure, of connecting the maxillary with the tympanic; but the second division of the appendage (squamosal) which began to expand in the lower mammalia, and to strengthen, without actually forming part, of the walls of the brain-case, now attains its maximum of development, and forms an integral constituent of the cranial parietes, filling up a large cavity between the neural arches of the occipital and parietal segments. It coalesces, moreover, with the tympanic, mastoid, and petrosal, and forms, with the subsequently anchylosed stylohyal, a compound bone called "temporal" in human anatomy. The key to the complex beginning of this "cranial" bone is again given by the discovery of the general pattern on which the skulls of the vertebrate animals have been constructed. In relation to that pattern, or to the archetype vertebrate skeleton, the human temporal bone includes two pleurapophyses, 38 and 28, a parapophysis, 8, part of a diverging appendage, 27, and a sense-capsule, 16.

The departure from the archetype, which we observe in the human skull, is most conspicuous in the neural spines of the three chief segments, which, archetypally, may be regarded as deformities by excess of growth to fulfil a particular use, dependent on the maximization of the brain; the deviation is again marked by arrest of growth or suppression of parts, as *e.g.* in certain parapophyses, and in the hæmal arch of the parietal segment; it is most frequently exemplified in the coalescence of parts primarily and archetypally distinct; and it is finally manifested by the dislocation of a part—viz., the hæmal arch of the occipital segment—the diverging rays of which have become the seat of that marvellous development which has resulted in the formation of the osseous basis of the human hand and arm. With the above explanation the structure of the human skull can be intelligibly comprehended, and not merely empirically understood, as through the absolute descriptions penned in reference to material and utilitarian requirements, and without reference to the great scale of vertebrate structures, of which man is the summit.

The fruit of a series of comparisons, extended over all the vertebrate kingdom, being the recognition of the archetype governing the structure of the vertebrate skeleton, the expression of such knowledge has necessitated the use of general terms, such as "vertebra," for the segments of the skeleton, "neurapophyses," for a constant element of such segment, and the like "general names" for other elements. When any of these elements are modified for special functions, then also a special name for it becomes a convenience, as when a "pleurapophysis" becomes a jaw or blade-bone, &c., a "diverging appendage" an arm or a leg. Deep thinking anatomists have heretofore caught glimpses of these higher, or more general, relations of the vertebral elements, when much modified or specialized, as *e.g.* in the head, and have tried to give expression to the inchoate notion, as when Spix called the "maxillary arch" the "arm of the head." These glimpses of a great truth were, however, ill received; and Cuvier alluded to them, with ill-disguised contempt, as being unintelligible and mystical jargon, in his great work on Fossil Animals (1825). But the error or obscurity lay rather in the mode of stating the relationship of certain bones of the head to those of the trunk, than in the relationship itself: in the endeavour, *e.g.*, to express the relation by special instead of general terms. Even in 1845 the learned and liberal-minded editor of Baron Cuvier's last course of lectures, M. de Saint Agy, commenting upon the osteological essays of Spix and Oken, remarks: "For my part, an 'upper jaw' is an 'upper jaw,' and an 'arm' is an 'arm.' One must not seek to originate an osteology out of a system of metaphysics."* But a jaw is not the less a jaw because it is a "hæmapophysis," nor is an arm the less an arm because it is a "diverging appendage." In the same spirit a critic might write: "Newton calls this earth a 'planet,' and the moon a 'satellite;' for me the earth is an earth, and the moon is a moon. One must not strive to make an ouranology out of a system of metaphysics." After the first recognition of a thing, one may seek to penetrate, and succeed in knowing, its essential nature, and yet keep within the bounds of nature.

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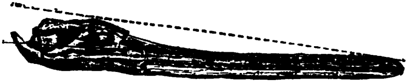
* "Pour moi, une mâchoire superieure est une mâchoire superieure, et un bras est un bras. Il ne faut pas chercher à faire sortir l'osteologie d'un systeme de metaphysique."

In no class of vertebrate animals is the progressive superiority of the cranium over the face marked by such distinct stages as in the mammalia. Various methods of determining these proportions have been proposed; but the only satisfactory one is by comparing vertical sections of the skull, as in the series figured in the cuts 47—52.

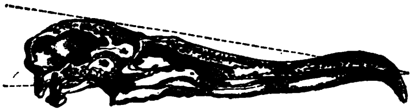
Fig. 47.



CROCODILE.

In the cold-blooded ferocious crocodile (Fig. 47), the cavity for the brain, in a skull three feet long, will scarcely contain a man's thumb. Almost all the skull is made up of the instruments for gratifying an insatiable propensity to slay and devour; it is the material symbol of the lowest animal passion.

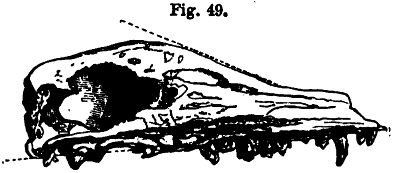
Fig. 48.



ALBATROSS.

In the bird (Fig. 48), the brain-case has expanded vertically and laterally, but is confined to the back part of the skull. In the small singing birds, with shorter beaks, the proportion of the cranial cavity becomes much greater. In the dog (Fig. 49), the brain-case, with more capacity, begins to advance further forward. In the chimpanzee (Fig 50), the capacities or area of the cranium and face are about equal. In man the cranial area vastly surpasses that of the face.

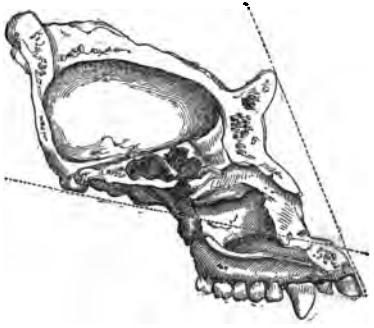
Fig. 49.



DOG.

A difference in this respect is noticeable between the savage (Fig. 51) and civilized (Fig. 52) races of mankind; but it is immaterial as compared with the contrast in this respect presented by the lowest form of the human head (Fig. 51) and the highest of the brute species (Fig. 50). Such as it is, however, the more contracted cranium is commonly accompanied by more produced premaxillaries and thicker walls of the cranial cavity, as is exemplified in the negro or Papuan skull.

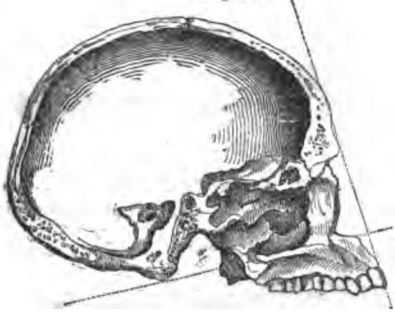
Fig. 50.



CHIMPANZEE.

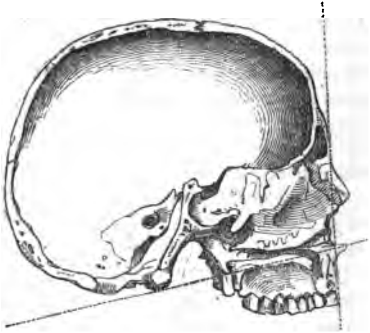
If a line be drawn from the occipital condyle along the floor of the nostrils, and be intersected by a second touching the most prominent parts of the forehead and upper jaw, the intercepted angle gives, in a general way, the proportions of the cranial cavity and the grade of intelligence; it is called the facial angle. In the dog this angle is 20°; in the great chimpanzee, or gorilla, it is 40°, but the prominent superorbital ridge occasions some exaggeration; in the Australian it is 85°; in the European it is 95°. The ancient Greek artists adopted, in their beau ideal of the beautiful and intellectual, an angle of 100.

Fig. 51.



AUSTRALIAN.

Fig. 52.



EUROPEAN.

CONCLUDING REMARKS.

A retrospect of the varied forms and proportions of the skeletons of animals, whether modified for aquatic, aerial, or terrestrial life, will show that whilst they were perfectly and beautifully adapted to the sphere of life and exigences of the species, they adhered with remarkable constancy to that general pattern or archetype which was first manifested on this planet, as Geology teaches, in the class of fishes, and which has not been departed from even in the most extremely modified skeleton of the last and highest form which Creative Wisdom has been pleased to place upon this earth.

It is no mere transcendental dream, but true knowledge and legitimate fruit of inductive research, that clear insight into the essential nature of each element of the bony framework, which is acquired by tracing them step by step, as, *e.g.*, from the unbranched pectoral ray of the lepidosiren to the equally small and slender but bifid pectoral ray of the amphiume, thence to the similar but trifid ray of the proteus, and through the progressively superadded structures and perfections of the limbs in higher reptiles and in mammals. If the special homology of each part of the diverging appendage and its supporting arch are recognisable from man to the fish, we cannot close the mind's eye to the evidences of that higher law of archetypal conformity on which the very power of tracing the lower and more special correspondences depend.

Buffon has well remarked, in the Introduction to his great work on Natural History, " It is only by comparing that we can judge, and our knowledge turns entirely on the relations that things bear to those which resemble them and to those which differ from them; so, if there were no animals, the nature of man would be far more incomprehensible than it is."

And if this be true, as to man's general nature and powers, it is equally so with regard to his anatomical structure.

In the same spirit our philosophic poet felt that—

" 'Tis the sublime of man,
Our noontide majesty, to know ourselves
Part and proportions of a wondrous whole."—COLERIDGE.

Vertebrated animals of progressively higher grades of structure have existed at successive periods of time on this planet, and they were constructed on a common plan with those that still exist.

Some have concluded, therefore, that the characters of a species became modified in successive generations, and that it was transmuted into a higher species; a reptile, *e.g.*, into a mammal; an ape, into a negro. Let us consider, therefore, the import and value of the osteological differences between the gorilla—the highest of all apes—and man, in reference to this "transmutation hypothesis." The skeleton of an animal may be modified to a certain extent by the action of the muscles. By the development of the processes, ridges, and crests, the anatomist judges of the muscular power of the individual to whom a skeleton under comparison has appertained. A very striking difference from the form of the human cranium results from the development of certain crests and ridges for the attachment of muscles, in the great apes; but none of the more important differences on which the naturalist relies for the determination of the genus and species of the orangs and chimpanzees have such an origin or dependent relation. The great superorbital ridge, *e.g.*, against which the facial line rests in Fig. 50, is not the consequence of muscular action or development: it is characteristic of the genus *Troglodytes* from the time of birth; and we have no grounds for believing it to be a character to be gained or lost through the operations of external causes, inducing particular habits through successive generations of a species.

No known cause of change productive of varieties of mammalian species could operate in altering the size, shape, or connections of the prominent premaxillary bones, which so remarkably distinguish the great *Troglodytes gorilla* from the lowest races of mankind. There is not, in fact, any other character than that founded upon the development of bone for the attachment of muscles, which is known to be subject to change through the operation and influence of external causes. Nine-tenths of the differences which have been cited (see the "Transactions of the Zoological Society," vol. iii., p. 418), as distinguishing the great chimpanzee from the human species, must stand in contravention of the hypothesis of transmutation and progressive development, until the acceptors of that hypothesis are enabled to adduce the facts demonstrative of the conditions of the modifiability of such characters. Moreover, as the generic forms of the ape tribe approach the human type, they are represented by fewer species. The unity of the human species is demonstrated by the constancy of those osteological and dental peculiarities which are seen to be most characteristic of the *bimana* in contradistinction from the *quadrumana*.

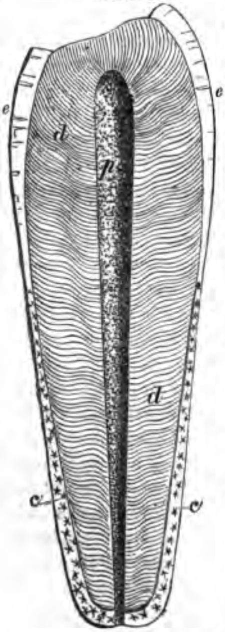
Man is the sole species of his genus (*homo*)—the sole representative of his order (*bimana*); he has no nearer physical relations with the brute kind than those that belong to the characters which link together the unguiculate division of the mammalian class.

Of the nature of the creative acts by which the successive races of animals were called into being, we are ignorant. But this we know, that as the evidence of unity of plan testifies to the oneness of the Creator, so the modifications of the plan for different modes of existence illustrate the beneficence of the Designer. Those structures, moreover, which are at present incomprehensible as adaptations to a special end, are made comprehensible on a higher principle, and a final purpose is gained in relation to human intelligence; for in the instances where the analogy of humanly invented machines fails to explain the structure of a divinely created organ, such organ does not exist in vain if its truer comprehension, in relation to the Divine idea, or prime Exemplar, lead rational beings to a better conception of their own origin and Creator. RICHARD OWEN.

ON THE PRINCIPAL FORMS AND STRUCTURES OF THE TEETH.

At the commencement of the Treatise on the Principal Forms of the Skeleton, it was stated that "tooth," like "bone," was the result of the combination of certain earthy salts with a pre-existing cellular basis of animal matter. The salts, as shown in a subjoined table, are nearly the same as those in bone, but enter in a larger proportion into the composition of tooth, and render it a harder body. So composed, teeth are peculiar to the back-boned (vertebrate) animals, and are attached to parts of the mouth, commonly to the jaws. They present many varieties as to number, size, form, structure, position, and mode of attachment, but are principally adapted for seizing, tearing, dividing, pounding, or grinding the food. In some species they are modified to serve as formidable weapons of offence and defence; in others, as aids in locomotion, means of anchorage, instruments for uprooting or cutting down trees, or for transport and working of building materials. They are characteristic of age and sex; and in man they have secondary relations subservient to beauty and to speech.

Fig. 1.



SECTION OF HUMAN INCISOR TOOTH (magnified).

Teeth are always intimately related to the food and habits of the animal, and are therefore highly interesting to the physiologist: they form, for the same reason, important guides to the naturalist in the classification of animals; and their value, as zoological characters, is enhanced by the facility with which, from their position, they can be examined in living or recent animals; whilst the durability of their tissues renders them not less available to the palæontologist in the determination of the nature and affinities of extinct species, of whose organization they are often the sole remains discoverable in the deposits of former periods of the earth's history.

The substance of teeth is not so uniform as in bone, but consists commonly of two or more tissues, characterized by the proportions of their earthy and animal constituents, and by the size, form, and direction of the cavities in the animal basis which contain the earth, the fluid, or the vascular pulp.

The tissue which forms the body of the tooth is called "dentine" (*dentinum*, Lat.,) Fig. 1, *d*.

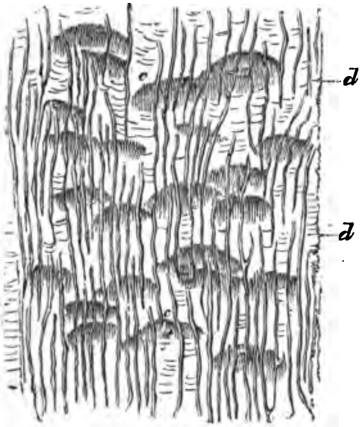
The tissue which forms the outer crust of the tooth is called the "cement" (*cæmentum*, and *crusta petrosa*, Lat.), *ib.*, *c*.

The third tissue, when present, is situated between the dentine and cement, and is called "enamel" (*encaustum*, or *adamas*, Lat.), *ib.*, *e*.

"Dentine" consists of an organized animal basis disposed in the form of extremely minute tubes and cells, and of earthy particles; these particles have a twofold arrangement, being either blended with the animal matter of the interspaces and parietes of the tubes and cells, or contained in a minutely granular state in their cavities. The density of the dentine arises principally from the proportion of earth in the first of these states of combination. The tubes and cells contain, besides the granular earth, a colourless fluid, probably transuded "plasma," or "liquor sanguinis," and thus relate not only to the mechanical conditions of the tooth, but to the vitality and nutrition of the dentine.

In hard or true dentine, the tubes called "dentinal tubes" diverge from the hollow of the tooth, called "pulp-cavity" (Fig. 1), *p*, and proceed with a slightly wavy course at right angles, or nearly so, to the outer surface. The hard substance of the tooth is thus arranged in hollow columns, perpendicular to the plane of pressure, and a certain elasticity results from their curves: they are upright where the grinding surface of the crown receives the appulse of the opposing tooth, and are horizontal where they have to resist the pressure of contiguous teeth. In Fig. 2, a highly magnified view is given of a small portion of human dentine, showing the tubuli, *d d*, in the intertubular substance, with the traces, *c c*, of the primitive cellular constitution of that substance. For the mode in which the nucleated cells of the primary basis of the tooth, called "tooth-pulp," are converted into dentine, reference may be made to the author's "Odontography" (Introd., plates 1 and 2). The tubuli, besides fulfilling the mechanical ends above stated, receive the plasma transuded from the remains of the vascular pulp, which circulates, by anastomosing branches of the tubuli and by the plasmatic cells of the intertubular substance, through the dentine, maintaining a sufficient though languid vitality of the tissue. The delicate nerve-branches on the pulp's surface, some minute production of which may penetrate the tubuli, convey sensations of impressions affecting the dentine—sensations of which every one has experienced the acuteness when decay has affected the dentine, or when mechanical or chemical stimuli have "set the tooth on edge:" but true "dentine" has no canals large enough to admit capillary vessels with the red particles of blood.

Fig. 2.



SECTION OF HUMAN TOOTH (highly magnified).

The first modification of dentine is that in which capillary tracts of the primitive vascular pulp remain uncalcified, and permanently carry red blood into the substance of the tissue. These so-called "vascular canals" present various dispositions in the dentine which they modify, and which modification is called "vaso-dentine." It is often combined with true dentine in the same tooth, *e.g.*, in the large incisors of certain rodents, the tusks of the elephant, the molars of the extinct iguanodon.

A second modification of the fundamental tissue of the tooth is where the cellular basis is arranged in concentric layers around the vascular canals, and contains "radiated cells" like those of the osseous tissue; it is called "osteo-dentine." The transition from dentine to vaso-dentine, and from this to osteo-dentine, is gradual, and the resemblance of osteo-dentine to true bone is very close.

"Cement" always closely corresponds in texture with the osseous tissue of the same animal; and wherever it occurs of sufficient thickness, as upon the teeth of the horse, sloth, or ruminant, it is also transversed, like bone, by vascular canals. In reptiles and mammals, in which the animal basis of the bones of the skeleton is excavated by minute radiated cells, these are likewise present, of similar size and form, in the cement, and are its chief characteristic as a constituent of the tooth. The relative density of the dentine and cement varies according to the proportion of the earthy material, and chiefly of that part which is combined with the animal matter in the walls of the cavities, as compared with the size and number of the cavities themselves. In the complex grinders of the elephant, the masked boar, and the capybara, the cement, which forms nearly half the mass of the tooth, wears down sooner than the dentine.

The "enamel" is the hardest constituent of a tooth, and consequently the hardest of animal tissues; but it consists, like the other dental substances, of earthy matter, arranged by organic forces in an animal matrix. Here, however, the earth is mainly contained in the canals of the animal membrane, and in mammals and reptiles, completely fills those canals, which are comparatively wide, whilst their parietes are of extreme tenuity.

CHEMICAL COMPOSITION OF TEETH.*

	MAN.		LION.		OX.			CROCODILE.		PIKE.
	Dentine.	Enamel.	Dentine.	Enamel.	Dentine.	Enamel.	Cement.	Dentine.	Cement.	Large teeth of lower jaw.
Phosphate of lime, with a trace of fluate of lime	66·72	89·82	60·03	83·33	59·57	81·86	58·73	53·69	53·39	63·98
Carbonate of lime . . .	3·36	4·37	3·00	2·94	7·00	9·33	7·22	6·30	6·29	2·54
Phosphate of magnesia . .	1·08	1·34	4·21	3·70	0·99	1·20	0·99	10·22	9·99	0·73
Salts	0·83	0·88	0·77	0·64	0·91	0·93	0·82	1·34	1·42	0·97
Chondrine	27·61	3·39	31·57	9·39	30·71	6·66	31·31	27·66	28·15	30·60
Fat	0·40	0·20	0·42	a trace	0·82	0·02	0·93	0·79	0·76	1·18
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

The examples are extremely few, and, as far as I know, are peculiar to the class *Pisces*, of calcified teeth, which consist of a single tissue, and this is always a modification of dentine. The large pharyngeal teeth of the wrasse (*Labrus*) consist of a very hard kind of dentine.

The next stage of complexity is where a portion of the dentine is modified by vascular canals. Teeth, thus composed of dentine and vasodentine, are very common in fishes.

The hard dentine is always external, and holds the place and performs the office of enamel in the teeth of higher animals. The grinding teeth of the dugong, and the conical teeth of the great sperm-whale, are examples of teeth composed of dentine and cement, the latter tissue forming a thick external layer.

In the teeth of the sloth, and its great extinct congener, the megatherium, the hard dentine is reduced to a thin layer, and the chief bulk of the tooth is made up of a central body of vaso-dentine, and a thick external crust of cement. The hard dentine is, of course, the firmest tissue of a tooth so composed, and forms the crest of the transverse ridges of the grinding surface, like the enamel plates in the elephant's grinder.

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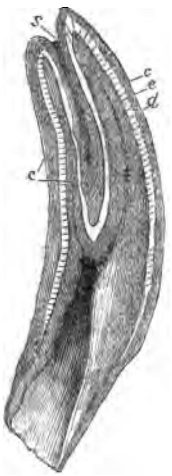
* Selected from the analytic tables given in the author's "Odontography," 4to, vol. i., pp. lxii.-lxiv. (1840).

Fig. 3.



SECTION OF HORSE'S INCISOR.

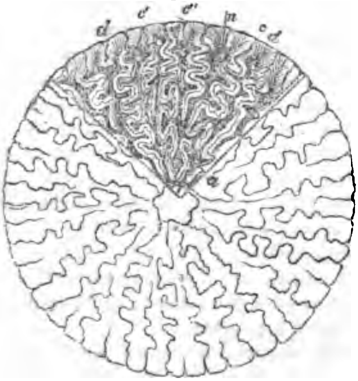
The human teeth, and those of the carnivorous mammals, appear at first sight to be composed of dentine and enamel only; but their crowns are originally, and their fangs are always, covered by a thin coat of cement. There is also commonly a small central tract of osteo-dentine in old teeth.

The teeth, called compound or complex, in *mammalia*, differ as regards their composition from the preceding only by the different proportion and disposition of the constituent tissues. Fig. 3 is a longitudinal section of the incisor of a horse; *d* is the dentine, *e* the enamel, and *c* the cement, a layer of which is reflected into the deep central depression of the crown; *s* indicates the coloured mass of tartar and particles of food which fills up the cavity, forming the "mark" of the horse-dealer.

A very complex tooth may be formed out of two tissues by the way in which these may be interblended, as the result of an original complex disposition of the constituents of the dental matrix.

Certain fishes, and a singular family of gigantic extinct batrachians, which I have called "Labyrinthodonts,"* exhibit, as the name implies, a remarkable instance of this kind of complexity. The tooth appears to be of the simple conical kind, with the exterior surface merely striated longitudinally; but, on making a transverse section, as in Fig. 4, each streak is a fissure into which the very thin external layer of cement, *c*, is reflected into the body of the tooth, following the sinuous wavings of the lobes of dentine, *d*, which diverge from the central pulp cavity, *a*. The inflected fold of cement, *c*, runs straight for about half a line, and then becomes wavy, the waves rapidly increasing in breadth as they recede from the periphery of the tooth; the first two, three, or four undulations are simple, then their contour itself becomes broken by smaller or secondary waves; these become stronger as the fold approaches the centre of the tooth, when it increases in thickness, and finally terminates by a slight dilatation or loop close to the pulp-cavity, from which the free margin of the inflected fold of cement is separated by an extremely thin layer of dentine. The number of the inflected converging folds of dentine is about fifty at the middle of the

Fig. 4.



TRANSVERSE SECTION OF TOOTH OF LABYRINTHODON.

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* "Proceedings of the Geological Society," Jan. 20, 1841, p. 257.

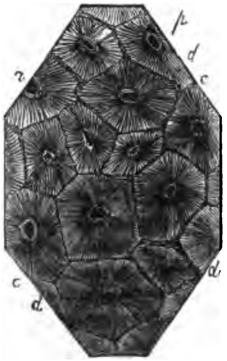
crown of the tooth, but is greater at the base. All the inflected folds of cement, at the base of the tooth, have the same complicated disposition with increased extent; but, as they approach their termination towards the upper part of the tooth, they also gradually diminish in breadth, and consequently penetrate to a less distance into the substance of the tooth. Hence, in such a section as is delineated (Fig. 4), it will be observed that some of the convoluted folds, as those marked *c c*, extend near to the centre of the tooth; others, as those marked *c'*, reach only about half way to the centre; and those folds, *c''*, which, to use a geological expression, are "cropping out," penetrate to a very short distance into the dentine, and resemble, in their extent and simplicity, the converging folds of cement in the fangs of the tooth of the ichthyosaurus.

The disposition of the dentine, *d*, is still more complicated than that of the cement. It consists of a slender, central, conical column, excavated, by a conical pulp-cavity, *a*, for a certain distance from the base of the tooth; and this column sends from its circumference, radiating outwards, a series of vertical plates, which divide into two, once or twice, before they terminate at the periphery of the tooth. Each of these diverging and dichotomising plates gives off, throughout its course, smaller processes, which stand at right angles, or nearly so, to the main plate. They are generally opposite, but sometimes alternate; many of the secondary plates or processes, which are given off near the centre of the tooth, also divide into two before they terminate, as at *n*; and their contour is seen, in the transverse section, to partake of all the undulations of the folds of cement which invest them, and divide the dentinal plates and processes from each other.

Another kind of complication is produced by an aggregation of many simple teeth into a single mass.

The examples of these truly compound teeth are most common in the class of fishes; but the illustration here selected is from the mammalian class. Each tooth of the Cape ant-eater (*Orycteropus*), presents a simple form, is deeply set in the jaw, but without dividing into fangs; its broad and flat base is porous, like the section of a common cane. The canals to which these pores lead, contain processes of a vascular pulp, and are the centres of radiation of as many independent series of dentinal tubules. Each tooth, in fact, consists of a congeries of long and slender prismatic denticles of dentine, which are cemented together by their ossified capsules, the columnar denticles slightly decreasing in diameter, and occasionally bifurcating as they approach the grinding surface of the tooth. Fig. 5 gives a magnified view of a portion of the transverse section of the fourth molar, showing *c*, the cement; *d*, the dentine; and *p*, the pulp-cavity of the denticles.

Fig. 5.

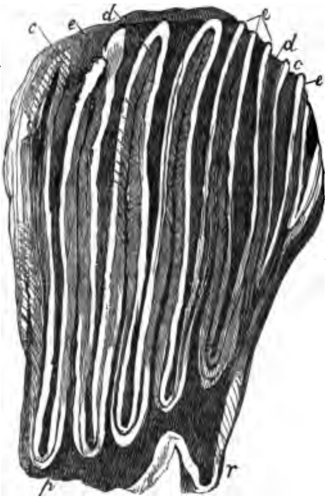


TRANSVERSE SECTION OF PART OF TOOTH OF *Orycteropus* (magnified).

In the elephant the denticles of the compound molars are in the form of plates, vertical to the grinding surface and transverse to the long diameter of the tooth. When the tooth is bisected vertically and lengthwise, the three substances, *d*, dentine, *e*, enamel, and *c*, cement, are seen interblended, as in Fig. 6, in which *p* is the common pulp-cavity, and *r* one of the roots of this complex tooth.

Such are some of the prominent features of a field of observation which Comparative Anatomy opens out to our view—such the varied nature, and such the gradation of complexity of the dental tissues, which, up to December, 1839, continued, notwithstanding successive approximations to the truth, to be described, in systematic works, as a "phaneros," or "a dead part or product, exhaled from the surface of a formative bulb!"*

Fig. 6.

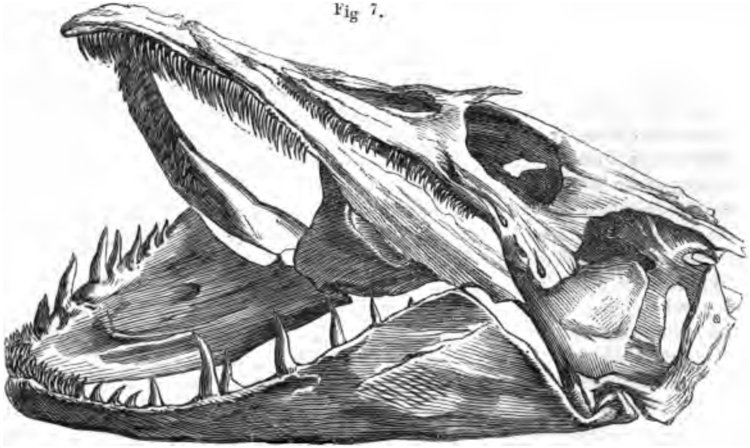


LONGITUDINAL SECTION OF PART OF GRINDER OF ELEPHANT.

Dental System of Fishes.—The teeth of fishes, whether we study them in regard to their number, form, substance, structure, situation, or mode of attachment, offer a greater and more striking series of varieties than do those of any other class of animals.

As to number, they range from zero to countless quantities. The lancelet, the ammocete, the sturgeon, the paddle-fish, and the whole order of *lophobranchii*, are edentulous. The myxinoids have a single pointed tooth on the roof of the mouth, and two serrated dental plates on the tongue. The tench has a single grinding tooth on the occiput, opposed to two dentigerous pharyngeal jaws below. In the lepidosiren a single maxillary dental plate is opposed to a single mandibular one, and there are two small denticles on the nasal bone. In the extinct sharks with crushing teeth, called *ceratodus* and *tenodus*, the jaws were armed with four teeth, two above and two below. In the *himæræ*, two mandibular teeth are opposed to four maxillary teeth. From this low point

Fig 7.



SKULL OF THE PIKE, SHOWING THE TEETH.

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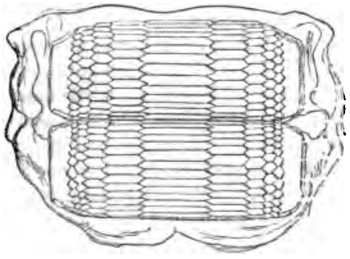
* See the Fasciculus of M. de Blainville's great work, "Ostéographie et Odontographie d'Animaux Vertébrés," which he submitted to the Academy of Sciences of the Institute of France on the same day, December 16th, 1839, on which I communicated, on the occasion of my election as corresponding member of that body, my "Theory of the development of dentine by centripetal calcification and conversion of the cells of the pulp."

the number in different fishes is progressively multiplied, until in the pike (Fig. 7), the siluroids, and many other fishes, the mouth becomes crowded with countless teeth.

With respect to form, it may be premised that, as organized beings withdraw themselves more and more, in their ascent in the scale of life, from the influence of the general polarizing forces, so their parts progressively deviate from geometrical figures: it is only, therefore, in the lowest vertebrated class that we find teeth in the form of perfect cubes, and of prisms or plates with three sides (as in *myletes*), four sides (as in *scarus*), five or six sides (as in *myliobates*, Fig. 8). The cone is the most common form in fishes: such teeth may be slender, sharp-pointed, and so minute, numerous, and closely aggregated, as to resemble the plush or pile of velvet. These are called "villiform teeth" (*dentes villiformes*, Lat.; *dents en velours*, Fr.) All the teeth of the perch are of this kind. When the teeth are equally fine and numerous, but longer, these are called "ciliiform" (*dentes ciliiformes*); when the teeth are similar to but rather stronger than these, they are called "setiform" (*dentes setiformes*, Lat.; *dents en brosse*, Fr.): the teeth in the upper jaw of the pike (Fig. 7) are of this kind. Conical teeth, as close-set and sharp-pointed as the villiform teeth, but of larger size, are called "rasp-teeth" (*dentes raduliformes*, Lat.; *dents en rape*, or *en cardes*, Fr.): the pike presents such teeth on the back part of the vomer. The teeth of the sheat-fish (*Silurus glanis*) present all the gradations between the villiform and raduliform types. Setiform teeth are common in the fishes thence called Chætodonts; in the genus *Citharinæ* they bifurcate at their free extremities; in the genus *Platax* they end there in three diverging points, and the cone here merges into the long and slender cylinder. Sometimes the cone is compressed into a slender trenchant blade: and this may be pointed and recurved, as in the *muræna*; or barbed, as in *trichiurus* and some other Scomberoids; or it may be bent upon itself, like a tenter-hook, as in the fishes thence called *Goniodonts*. In the bonito may be perceived a progressive thickening of the base of the conical teeth; and this being combined in other predatory fishes with increased size and recurved direction, they then resemble the laniary or canine teeth of carnivorous quadrupeds, as we see in the large teeth of the pike (Fig. 7), in the lophius, and in certain sharks.

Fig. 8.



JAWS AND TEETH OF THE STING-RAY (*Myliobates*).

The anterior diverging grappling teeth of the wolf-fish (Fig. 9), *i*, form stronger cones; and by progressive blunting, flattening, and expansion of the apex, observable in different fishes, the cone gradually changes to the thick and short cylinder, such as is seen in the back teeth of the wolf-fish, *m*, and in similar grinding and crushing teeth in other genera, whether the fishes be feeders on sea-weeds, or on crustaceous and testaceous animals. The grinding surface of these short cylindrical teeth may be convex, as in the sheep's-head fish (*Sargus*); or flattened, as in the pharyngeal teeth of the wrasse (*Labrus*). Sometimes the hemispheric teeth are so numerous, and spread over so broad a surface, as to resemble a pavement, as in the pharyngeal bones of the wrasse; or they may be so small, as well as numerous, as to give a granulated surface to the part of the mouth to which they are attached, when they are called, in ichthyology, *dentes graniformes*.

A progressive increase of the transverse over the vertical diameter may be traced in the molar teeth of different fishes, and sometimes in those of the same individual, as in *labrus*, until the cylindrical form is exchanged for that of the depressed plate. Such dental plates (*dentes lamelliformes*) may be formed not only circular, but elliptical, oval, semilunar, sigmoid, oblong, or even square, hexagonal, pentagonal, or triangular; and the grinding surface may present various and beautiful kinds of sculpturing. The broadest and thinnest lamelliform teeth are those that form the complex grinding tubercle of the diodon.

In the sharks and rays the teeth are supported by the upper and lower jaws, as in most quadrupeds; but many other fishes have teeth growing from the roof of the mouth, from the surface of the tongue, from the bony hoops or arches supporting the gills, and some have them developed from the bone of the nose and the base of the skull. In the carp and tench the teeth are confined to this latter unusual position, and to a pair of bones, called "pharyngeal," which circumscribe the back outlet of the mouth.

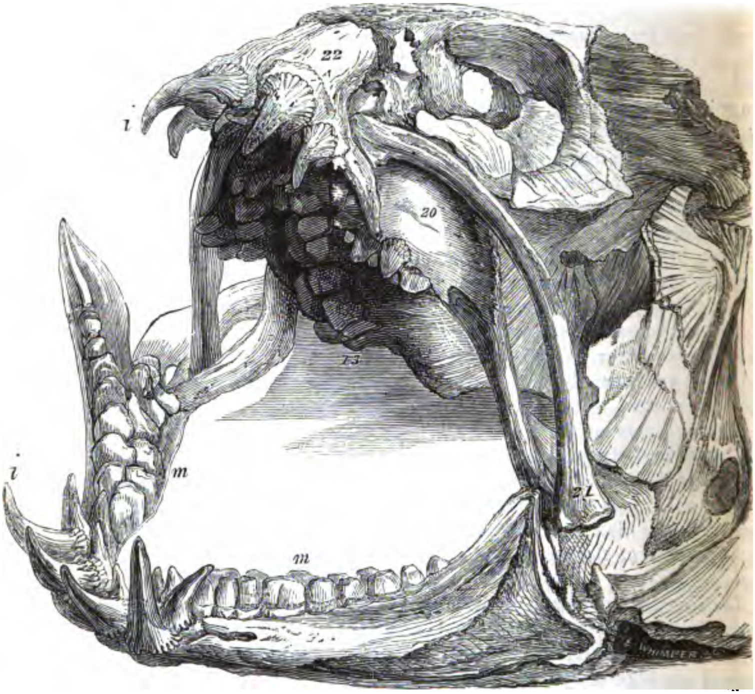
Fishes exhibit, moreover, a greater range of variety in the mode of attachment of the teeth than any other class of animals. In the sharks, and the singular fish called the "angler," the teeth are moveable, their base being tied by ligaments to the jaw. In the angler the ligaments are so inserted that they do not permit the teeth to be bent outwards beyond the vertical position, but yield to pressure in the contrary direction, by which the point of the tooth may be directed towards the back of the mouth; the instant, however, that the pressure is remitted, the tooth returns through the elasticity of the bent ligaments, as by the action of a spring, to its usual erect position; the deglutition of the prey of this voracious fish is thus facilitated, and its escape prevented. The broad and generally bifurcate bony base of the teeth of sharks is attached by ligaments to the semi-ossified crust of the cartilaginous jaws; but they have no power of erecting or depressing the teeth at will.

The teeth of the sphyræna are examples of the ordinary implantation in sockets, with the addition of a slight anchylosis of the base of the fully-formed tooth with the alveolar walls; and the compressed rostral teeth of the saw-fish are deeply implanted in sockets; the hind margin of their base is grooved, and a corresponding ridge from the back part of the socket fits into the groove, and gives additional fixation to the tooth.

The singular and powerfully developed dental system of the wolf-fish (*Anarrhicas lupus*, Fig. 9) has been a subject of interest to many anatomists. Most of the teeth are powerful crushers; some present the laniary type, with the apices more or less recurved and blunted by use, and consist of strong cones, spread abroad, like grappling hooks, at the anterior part of the mouth, *i*, *i*.

The premaxillary teeth, 22, *i*, are all conical, and arranged in two rows; there are two, three, or four in the exterior row, at the mesial half of the bone, which are the largest; and from six to eight smaller teeth are irregularly arranged behind. There are three large, strong, diverging laniaries at the anterior end of each premandibular bone, and immediately behind these an irregular number of shorter and smaller conical teeth, which gradually exchange this form for that of large obtuse tubercles, *m*, *m*; these extend backwards, in a double alternate series, along a great part of the alveolar border of the bone, and are terminated by two or three smaller teeth in a single row, the last of which again presents the conical form. Each palatine bone, 20, supports a double row of teeth, the outer ones being conical and straight, and from four to six in number; the inner ones two, three, or four in number, and tuberculate. The lower surface of the vomer, 13, is covered by a double irregularly alternate series of the same kind of large tuberculate crushing teeth as those at the middle of the premandibular bone. Thus the inside of the mouth appears to be paved with teeth, by means of which the wolf-fish can break in pieces the shells of whelks and lobsters, and effectually disengage the nutritious animal parts from them. All the teeth are anchylosed to more or less developed alveolar eminences of bones. From the enormous power of the muscles of the jaws, and the strength of the shells which are cracked and crushed by the teeth, their fracture and displacement must obviously be no unfrequent occurrence; and most specimens of the jaws of the wolf-fish exhibit some of the teeth either separated at this line of imperfect anchylosis, or, more rarely, detached by fracture of the supporting osseous alveolar process.

Fig. 9.



TEETH OF THE WOLF-FISH (*Anarrhicas*).

Thus, with reference to the main and fundamental tissue of tooth, we find not fewer than six leading modifications in fishes.

Hard or true dentine—Sparoids, labroids, lophius, balistes, pycnodonts, prionodon, sphyræna, megalichthys, rhizodes, diodon, scarus;

Osteodentine — Cestracion, acrodus, lepidosiren, ctenodus, hybodus, percoids, sciænoids, cottoids, gobioids, sharks, and many others;

Vasodentine—Psammodus, chimæroids, pristis, myliobates;

Plicidentine—Lophius, holoptychius, bothriolepis; and

Dendrodentine—Dendrodus;

Besides the compound teeth of the scarus and diodon.

One structural modification may prevail in some teeth, another in other teeth, of the same fish; and two or more modifications may be present in the same tooth, arising from changes in the process of calcification and a persistency of portions or processes of the primitive vascular pulp or matrix of the dentine.

The dense covering of the beak-like jaws of the parrot-fishes (*Scari*) consists of a stratum of prismatic denticles, standing almost vertically to the external surface of the jaw bone; this peculiar armature of the jaws is adapted to the habits and exigencies of a tribe of fishes which browse upon the lithophytes that clothe, as with a richly tinted carpet, the bottom of the sea, just as the ruminant quadrupeds crop the herbage of the dry land.

The irritable bodies of the gelatinous polypes which constitute the food of these fishes' retreat, when touched, into their star-shaped stony shells, and the *scari* consequently require a dental apparatus strong enough to break off or scoop out these calcareous recesses. The jaws are, therefore, prominent, short, and stout, and the exposed portions of the premaxillaries and premandibulars are incased by a complicated dental covering. The polypes and their cells are reduced to a pulp by the action of the pharyngeal jaws and teeth that close the posterior aperture of the mouth.

There is a close analogy between the dental mass of the scarus and the complicated grinders of the elephant, both in form, structure, and in the reproduction of the component denticles in horizontal succession. But in the fish, the complexity of the triturating surface is greater than in the mammal, since, from the mode in which the wedge-shaped denticles of the scarus are implanted upon, and anchylosed to, the processes of the supporting bone, this likewise enters into the formation of the grinding surface when the tooth is worn down to a certain point.

The proof of the efficacy of the complex masticatory apparatus above described, is afforded by the contents of the alimentary canal of the scari. Mr. Charles Darwin, the accomplished naturalist and geologist, who accompanied Captain Fitzroy, R.N., in the circumnavigatory voyage of the "Beagle," dissected several parrot-fishes soon after they were caught, and found the intestines laden with nearly pure chalk, such being the nature of their excrements; whence he ranks these fishes among the geological agents to which is assigned the office of converting the skeletons of the lithophytes into chalk.

The most formidable dentition exhibited in the order of osseous fishes is that which characterizes the sphyræna, and some extinct fishes allied to this predatory genus. In the great barracuda of the southern shores of the United States (*Sphyræna barracuda*, Cuv.) the lower jaw contains a single row of large, compressed, conical, sharp-pointed, and sharp-edged teeth, resembling the blades of lancets, but stronger at the base; the two anterior of these teeth are twice as long as the rest, but the posterior and serial teeth gradually increase in size towards the back part of the jaw; there are about twenty-four of these piercing and cutting teeth in each premandibular bone. They are opposed to a double row of similar teeth in the upper jaw, and fit into the interspace of these two rows when the mouth is closed. The outermost row is situated on the intermaxillary, the innermost on the palatine bones; there are no teeth on the vomer or superior maxillary bones. The two anterior teeth in each premaxillary bone equal the opposite pair in the lower jaw in size; the posterior teeth are serial, numerous, and of small size; the second of the two anterior large premaxillary teeth is placed on the inner side of the commencement of the row of small teeth, and is a little inclined backwards. The retaining power of all the large anterior teeth is increased by a slight posterior projection, similar to the barb of a fish-hook, but smaller. The palatine bones contain each nine or ten lancet-shaped teeth, somewhat larger than the posterior ones of the lower jaw. All these teeth afford good examples of the mode of attachment by implantation in sockets, which has been denied to exist in fishes.

The loss or injury to which these destructive weapons are liable, in the conflict which the sphyræna wages with its living and struggling prey, is repaired by an uninterrupted succession of new pulps and teeth. The existence of these is indicated by the foramina, which are situated immediately posterior to, or on the inner margin of, the sockets of the teeth in place; these foramina lead to alveoli of reserve, in which the crowns of the new teeth in different stages of development are loosely imbedded. It is in this position of the germs of the teeth that the sphyrænoid fishes, both recent and fossil, mainly differ, as to their dental characters, from the rest of the scomberoid family, and proportionally approach the sauroid type.

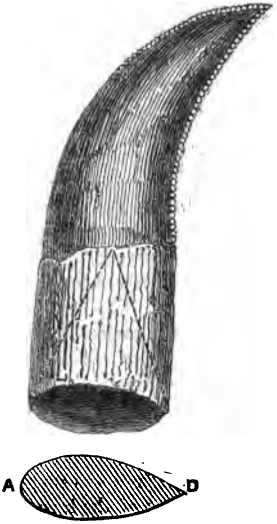
In all fishes the teeth are shed and renewed, not once only, as in mammals, but frequently during the whole course of their lives. The maxillary dental plates of lepidosiren, the cylindrical dental masses of the chimæroid and edaphodont fishes, and the rostral teeth of the saw-fish (if these modified dermal spines may be so called) are, perhaps, the sole examples of "permanent teeth" to be met with in the whole class. In the great majority of fishes, the germs of the new teeth are developed like those of the old, from the free surface of the buccal membrane throughout the entire period of succession; a circumstance peculiar to the present class. The angler, the pike, and most of our common fishes, illustrate this mode of dental reproduction; it is very conspicuous in the cartilaginous fishes (Fig. 8, *e. g.*), in which the whole phalanx of their numerous teeth is ever marching slowly forwards in rotatory progress over the alveolar border of the jaw, the teeth being successively cast off as they reach the outer margin, and new teeth rising from the mucous membrane behind the rear rank of the phalanx.

This endless succession and decadence of the teeth, together with the vast number in which they often co-exist in the same fish, illustrate the law of "vegetative or irrelative repetition," as it manifests itself on the first introduction of new organs in the animal kingdom, under which light we must view the above-described organized and calcified preparatory instruments of digestion in the lowest class of the vertebrate series.

Dental System of Reptiles.—In the class reptilia an entire order (*Chelonia*), including the tortoises, terrapenes, and turtles, are devoid of teeth; but the jaws in these edentulous reptiles are covered by a sheath of horn, which in some species is of considerable thickness and density; its working surface is trenchant in the carnivorous species, but is variously sculptured and adapted for both cutting and bruising in the vegetable feeders. No species of toad possesses teeth; neither have the jaws the compensatory covering above described in the chelonians. Frogs have teeth in the upper but not in the lower jaw. Newts and salamanders have teeth in both jaws, and also upon the palate; and teeth are found in the latter situation as well as on the jaws in most serpents and in the iguana lizard. In most other lizards and in crocodiles the teeth are confined to the jaws: in the former they are cemented or anchylosed to the jaw; in the latter they are implanted in sockets.

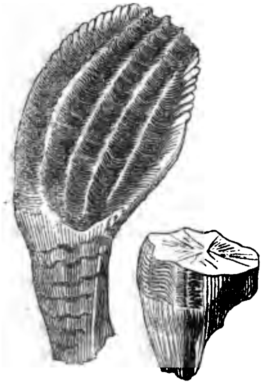
The existing lizards exhibit many modifications in the form of the teeth according to the nature of the food. They are pointed with sharp cutting edges in the great carnivorous monitor (*Varanus*), and are obtuse and rounded like paving-stones in the herbivorous or mixed feeding scinks, called, on account of the shape of the teeth, *cyclodus*. The gigantic extinct lizards showed similar modifications of their teeth. The megalosaurus had teeth which combined the properties of the knife, the sabre, and the saw (Fig. 10). When first protruded above the gum, the apex of the tooth presented a double cutting edge of serrated enamel; its position and line of action were nearly vertical, and its form, like that of the two-edged sword, cutting equally on each side. As the tooth advanced in growth it became curved backwards in the form of a pruning-knife, and the edge of serrated enamel was continued downwards to the base of the concave and cutting side of the tooth; whilst on the other side a similar edge descended but a short distance from the point, and the convex part of the tooth became blunt and thick, as the back of a knife is made thick for the purpose of producing strength. In a tooth thus formed for cutting along its concave edge, each movement of the jaw combined the power of the knife and the saw. The backward curvature of the full-grown teeth enables them to retain, like barbs, the prey which they had penetrated.

Fig. 10.



TOOTH OF THE MEGALOSAURUS.

Fig. 11.



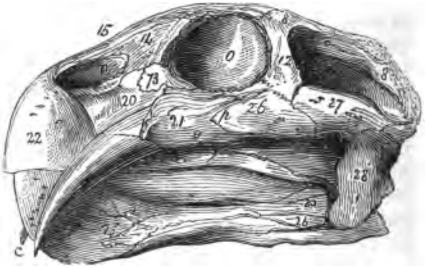
NEW-FORMED AND WORN TEETH OF THE IGUANODON.

In the iguanodon—the gigantic contemporary of the megalosaurus—the crown of the teeth (Fig. 11) was so shaped, that after the apex became worn down, it presented a broad and nearly horizontal surface, exposing dental substances of four different degrees of density,—viz., a ridge of enamel along the outer border of the crown; a layer of hard or unvascular dentine next to this; a layer of softer vascular dentine forming the inner half of the crown; and a portion of firm osteo-dentine in the middle of the grinding surface, formed by the ossified remnant of the tooth-pulp. The series of complex teeth, so constructed, seems to have been admirably adapted to the cropping and comminution of such tough vegetable food as the *clathrariæ* and similar now extinct plants, the fossil remains of which are found buried with those of the iguanodon. No existing reptile now presents so complicated a structure of the tooth in relation to vegetable food. The still more complex, and indeed marvellous structure of the teeth of the extinct gigantic lizard-like toad, called *Labyrinthodon*, has been already noticed (Fig. 4, p. 265). But, perhaps, the most singular dental structure yet found in the ancient members of the class Reptilia, is that presented by certain species of fossil found in South Africa, and probably from a geological formation nearly as old as our coal strata. I have called them "Dicynodonts," from their dentition being reduced to one long and large canine tooth on each side of the upper jaw. As these teeth give, at first sight, a character to the jaws like that which the long poison-fangs give, when erected, to the jaws of the rattlesnake, I shall briefly notice their characters before entering upon the description of the more normal saurian dentition.

Fig. 12 gives a reduced side view of the skull and teeth of the *Dicynodon lacerticeps.*

The maxillary bone, 21, is excavated by a wide and deep alveolus, with a circular area of half an inch, and lodges a long and strong, slightly curved, and sharp-pointed, canine tooth or tusk, which projects about two-thirds of its length from the open extremity of the socket. The direction of the tusks is forwards, downwards, and very slightly inwards; the two converging in the descent along the outer side of the compressed symphysis of the lower jaw, *c c.* The tusk is principally composed of a body of compact unvascular dentine. The base is excavated by a wide conical pulp-cavity, *p*, with the apex extending to about one-half of the implanted part of the tusk, and a linear continuation extending along the centre of the solid part of the tusk.

Fig. 12.



SKULL AND TUSKS OF *Dicynodon lacerticeps.*

Until the discovery of the rhynchosaurus, this edentulous and horn-sheathed condition of the jaws was supposed to be peculiar to the chelonian order among reptiles; and it is not one of the least interesting features of the dicynodonts of the African sandstones, that they should repeat a chelonian character hitherto peculiar amongst lacertians, to the above-cited remarkable extinct edentulous genus of the new red sandstone of Shropshire; but our interest rises almost to astonishment, when in a saurian skull we find, superadded to the horn-clad mandibles of the tortoise, a pair of tusks, borrowed, as it were, from the mammalian class, or rather foreshadowing a structure which, in the existing creation, is peculiar to certain members of the highest organized warm-blooded animals.

In the other reptilia, recent or extinct, which most nearly approach the mammalia in the structure of their teeth, the difference characteristic of the inferior and cold-blooded class is manifested in the shape, and in the system of shedding and succession of the teeth; the base of the implanted teeth seldom becomes consolidated, never contracted to a point, as in the fangs of the simple teeth of mammalia, and at all periods of growth one or more genus of teeth are formed within or near the base of the tooth in use, prepared to succeed it, and progressing towards its displacement. The dental armature of the jaws is kept in serviceable order by uninterrupted change and succession; but the forming organ of the individual tooth is soon exhausted, and the life of the tooth itself may be said to be comparatively short.

If one of the conical, sharp-pointed, and two-edged teeth of the Gangetic crocodile, called "garrhial" by the Hindoos, be extracted, its base will be found hollow, and partly absorbed or eaten away, as at *a*, Fig. 13; and within the cavity will be seen the half-formed succeeding tooth, *b*; at the base of which may probably be found the beginning or germ, *c*, of the successor of that tooth: all the teeth in the crocodile tribe being pushed out and replaced in the vertical direction by new teeth, as long as they live. The individual teeth increase in size as the animal grows; but the number of teeth remains the same from the period when the crocodile quits the egg to the attainment of its full size and age. No sooner has the young tooth penetrated the interior of the old one, than another germ begins to be developed from the angle between the base of the young tooth and the inner alveolar process, or in the same relative position as that in which its immediate predecessor began to rise; and the processes of succession and displacement are carried on, uninterruptedly, throughout the long life of these cold-blooded carnivorous reptiles. The fossil jaws of the extinct crocodiles demonstrate that the same law regulated the succession of the teeth at the ancient epochs when they prevailed in greatest numbers, and under the most varied specific modifications, as at the present day, when they are reduced to a single family.

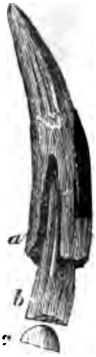
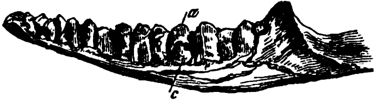


Fig. 13.

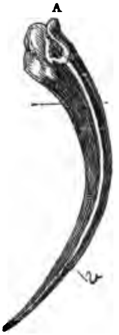


TOOTH, WITH GERMS OF SUCCESSORS, OF THE GARRHIAL (*Gavialis gangeticus*).

The most complex condition of the dental system in the reptile class is that which is presented by the poisonous serpents, in which certain teeth are associated with the tube or duct of a poison-bag and gland.

These teeth, called "poison-fangs," are confined to those bones of the upper jaw called "maxillary," and are usually single, or, when more, one only is connected with the poison-apparatus, and the others are either simple teeth, or preparing to take the place of the poison-fang.

Fig. 14.



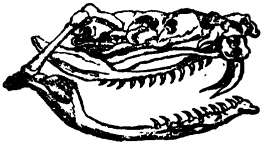
POISON-FANG OF RATTLE-SNAKE (Magnified).

To give an idea of the structure of this tooth, we may suppose a simple slender tooth, like that of a boa-constrictor, to be flattened, and its edges then bent towards each other and soldered together so as to form a tube, open at both ends, and inclosing the end of the poison-duct. Such a tooth is represented at Fig. 14, where A is the oblique opening penetrated by the duct, and *v* the narrower fissure by which the venom escapes.

The duct which conveys the poison, although it runs through the centre of the tooth, is really on the outside of the tooth. The bending of the dentine about it begins a little beyond the base of the tooth, where the poison-duct rests in a slight groove or longitudinal indentation on the convex side of the fang; as it proceeds it sinks deeper into the substance of the tooth, and the sides of the groove meet and seem to coalesce, so that the trace of the inflected fold ceases, in some species, to be perceptible to the naked eye; and the fang appears, as it is commonly described, to be perforated by the duct of the poison-gland.

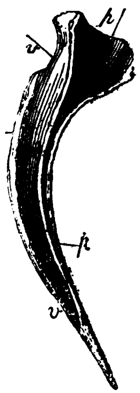
In the viper the line of union may be seen as marked at *v*, Fig. 14; and when such a tooth is carefully divided lengthwise, as in Fig. 15, the true pulp-cavity in the substance of the tooth is seen, as at *p p*, to terminate in a point; and the poison-canal, as at *u v*, to run along the forepart of the singularly modified tooth. This tooth is soldered to the maxillary bone (Fig. 16), which rotates so as to keep the tooth laid flat in the mouth at ordinary times, and to erect it when the deadly blow is about to be struck. The head of the snake is raised, drawn back, and the fangs, erect, and exposed by the widely open mouth, are struck, by the force of the powerful muscles of the head and neck, into the surface aimed at, the poison-bags at the same moment are squeezed, and their contents driven through the canal in the tooth into the wound. And here may be noticed the advantage of having the solid point of the tooth prolonged beyond the outlet of the poison canal and not weakened by its continuation to the apex.

Fig. 16.



SKULL OF A RATTLESNAKE (*Crotalus horridus*).

Fig. 15.



SECTION OF A POISON-FANG—RATTLESNAKE.

Dental System of Mammals.—The class *Mammalia*, like those of *Reptilia* and *Pisces*, includes a few genera and species that are devoid of teeth; the true ant-eaters (*myrmecophaga*), the scaly ant-eaters or pangolins (*manis*), and the spiny monotrematous ant-eater (*echidna*), are examples of strictly edentulous mammals. The ornithorhynchus has horny teeth, and the whales (*balæna* and *balænoptera*) have transitory embryonic calcified teeth, succeeded by whalebone substitutes in the upper jaw.

The female narwhal seems to be edentulous, but has the germs of two tusks in the substance of the upper jaw-bones; one of these becomes developed into a large and conspicuous weapon in the male narwhal, whence the name of its genus, of *monodon*, meaning single tooth. In another cetacean, the great bottle-nose or hyperoodon, the teeth are reduced in the adult to two in number, whence the specific name *H. bidens*, but they are confined to the lower jaw.

The elephant has never more than one entire molar, or parts of two, in use on each side of the upper and lower jaws; to which are added two tusks, more or less developed, in the upper jaw.

Some rodents, as the Australian water-rats (*Hydromys*), have two grinders on each side of both jaws; which, added to the four cutting teeth in front, make twelve in all; the common number of teeth in this order is twenty, but the hares and rabbits have twenty-eight each.

The sloth has eighteen teeth. The number of teeth, thirty-two, which characterizes man, the apes of the old world, and the true ruminants, is the average one of the class mammalia; but the typical number is forty-four.

The examples of excessive number of teeth are presented, in the order Bruta, by the priodont armadillo, which has ninety-eight teeth; and in the cetaceous order by the cachalot, which has upwards of sixty teeth, though most of them are confined to the lower jaw; by the common porpoise, which has between eighty and ninety teeth; by the Gangetic dolphin, which has one hundred and twenty teeth; and by the true dolphins (*delphinus*), which have from one hundred to one hundred and ninety teeth, yielding the maximum number in the class Mammalia.

Form.—Where the teeth are in excessive number, as in the species above cited, they are small, equal, or sub-equal, and usually of a simple conical form.

In most other mammalia particular teeth have special forms for special uses: thus, the front teeth, from being commonly adapted to effect the first coarse division of the food, have been called cutters or incisors; and the back teeth, which complete its comminution, grinders or molars; large conical teeth situated behind the incisors, and adapted by being nearer the insertion of the biting muscles to act with greater force, are called holders, tearers, laniaries, or more commonly canine teeth, from being well developed in the dog and other carnivora.

Molar teeth, which are adapted for mastication, have either tuberculate, or transversely ridged, or flat summits, and usually are either surrounded by a ridge of enamel, or are traversed by similar ridges arranged in various patterns.

The large molars of the capybara and elephant have the crown cleft into a numerous series of compressed transverse plates, cemented together side by side.

The teeth of the mammalia have usually so much more definite and complex a form than those of fishes and reptiles, that three parts are recognised in them—viz., the "fang," the "neck," and the "crown." The fang or root (*radix*) is the inserted part; the crown (*corona*) the exposed part; and the constriction which divides these is called the neck (*cervix*).

Fixation.—It is peculiar to the class mammalia to have teeth implanted in sockets by two or more fangs; but this can only happen to teeth of limited growth, and generally characterizes the molars and premolars; perpetually growing teeth require the base to be kept simple and widely excavated for the persistent pulp. In no mamiferous animal does anchylosis of the tooth with the jaw constitute a normal mode of attachment. Each tooth has its particular socket, to which it firmly adheres by the close co-adaptation of their opposed surfaces, and by the firm adhesion of the alveolar periosteum to the organized cement which invests the fang or fangs of the tooth.

True teeth implanted in sockets are confined, in the mammalian class, to the maxillary, premaxillary, and mandibular, or lower maxillary bones, and form a single row in each. They may project only from the premaxillary bones, as in the narwhal, or only from the lower maxillary bone, as in ziphius; or be apparent only in the lower maxillary bone, as in the cachalot; or be limited to the superior and inferior maxillaries, and not present in the premaxillaries, as in the true *pecora* (cow, sheep), and most *bruta* (sloth, armadillo) of Linnæus. In general, teeth are situated in all the bones above-mentioned. In man, where the premaxillaries early coalesce with the maxillary bones, where the jaws are very short and the crowns of the teeth are of equal length, there is no vacant space in the dental series of either jaw, and the teeth derive some additional fixity by their close apposition and mutual pressure. No inferior mammal now presents this character; but its importance, as associated with the peculiar attributes of the human organization, has been somewhat diminished by the discovery of a like contiguous arrangement of the teeth in the jaws of a few extinct quadrupeds, *e.g.*, anoplotherium, nesodon, and dichodon.

Structure.—The teeth of the mammalia usually consist of hard unvascular dentine, defended at the crown by an investment of enamel, and everywhere surrounded by a coat of cement. The coronal cement is of extreme tenuity in man, quadrumana, and the terrestrial carnivora; it is thicker in the herbivora, especially in the complex grinders of the elephant. Vertical folds of enamel and cement penetrate the crown of the tooth in the ruminants, and in most rodents and pachyderms, characterizing by their various forms the genera of the last two orders.

The teeth of the sloths, armadillos, and sperm-whales have no true enamel. The tusks of the narwhal, walrus, and elephant consist of modified dentine, which in the last great proboscidian animal is properly called "ivory," and is covered by cement.

The forming-organ of a mammalian tooth consists, as in the lower classes, of a pulp and a capsule. The substance of the pulp is converted into the "dentine;" that of the capsule into the "cement." Where enamel is to be added, a peculiar organ is formed on the inner surface of the capsule, which arranges the hardening material into the form, and of the density, characteristic of enamel. This substance is so hard in the tooth of the hippopotamus, as to "strike fire" like flint with steel. The whole forming-organ is called "matrix."

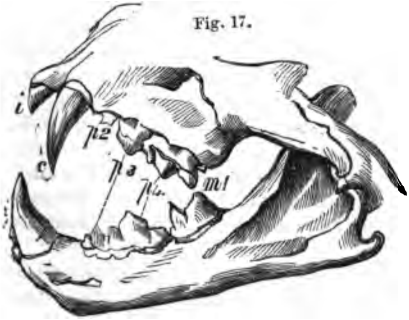
The matrix of certain teeth does not give rise during any period of their formation to the germ of a second tooth, destined to succeed the first; this tooth, therefore, when completed and worn down, is not replaced. The sperm whales, dolphins, and porpoises are limited to this simple provision of teeth. In the armadillos and sloths, the want of germinative power, as it may be called, in the matrix is compensated by the persistence of the matrix, and by the uninterrupted growth of the teeth.

In most other mammalia, the matrix of the first-developed tooth gives origin to the germ of a second tooth, which sometimes displaces the first, sometimes takes its place by the side of the tooth from which it has originated. All those teeth which are displaced by their progeny are called temporary, deciduous, or milk teeth; the mode and direction in which they are displaced and succeeded—viz., from above downwards in the upper, from below upwards in the lower jaw: in both jaws vertically—are the same as in the crocodile; but *the process is never repeated more than once in any mammiferous animal.* A considerable proportion of the dental series is thus changed; the second or permanent teeth having a size and form as suitable to the jaws of the adult as the displaced temporary teeth were adapted to those of the young animal.

The permanent teeth, which assume places not previously occupied by deciduous ones, are always the most posterior in their position, and generally the most complex in their form.

The term "molar," or "true molar," is restricted to these teeth; the teeth between them and the canines are called "premolars:" they push out the milk-teeth that precede them, and are usually of smaller size and simpler form than the true molars. They are called "bicuspids" in human anatomy.

Fig. 17.



JAWS AND TEETH OF THE LION.

Thus the class mammalia, in regard to the times of formation and the succession of their teeth, have been divided into two groups:—the *monophyodonts,** or those that generate a single set of teeth; and the *diphyodonts,*† or those that generate two sets of teeth.

I proceed next to notice the principal modifications of the teeth, as they are adapted to carnivorous, herbivorous, or mixed feeding habits in the diphyodont mammalia.

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* *μόνος*, once; *φύω*, I generate; *οδους*, tooth.

† *δις*, twice; *φύω* and *οδους*.

The lion may be taken as the type of the flesh-feeders (Fig. 17).

The largest and most conspicuous teeth in this and other feline quadrupeds are the "canines," *c*; they are of great strength, deeply implanted in the jaw, with the fang thicker and longer than the enamelled crown: this part is conical, slightly recurved, sharp-pointed, convex in front, almost flat on the inner side, and with a sharp edge behind. The lower canines pass in front of the upper ones when the mouth is closed.

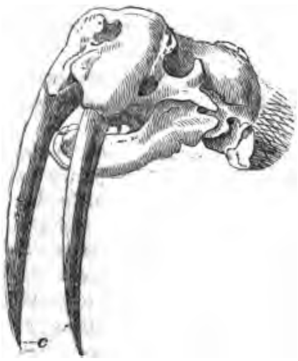
The incisors, six in number on both jaws, form a transverse row; the outermost above, *i*, is the largest, resembling a small canine: the intermediate ones have broad and thick crowns indented by a transverse cleft.

The first upper premolar, *p* 2, is rudimental: there is no answerable tooth in the lower jaw. The second, *p* 3, in both jaws has a strong conical crown supported on two fangs. The third upper tooth, *p* 4, has a cutting or trenchant crown, divided into three lobes, the last being the largest, and with a flat inner side, against which the cutting tooth, *m* 1, in the lower jaw works, like a scissor-blade. Behind, and on the inner side of the upper tooth, *p* 4, there is a small tubercular tooth, *m* 1. A glance at the long and strong, sub-compressed, trenchant, and sharp-pointed canines, suffices to appreciate their peculiar adaptation to seize, to hold, to pierce and lacerate a struggling prey. The jaws are strong, but shorter than in other carnivora, and with a concomitant reduction in the number of the teeth: thus the canines are brought nearer to the insertion of the very powerful biting muscles (called "temporal" and "masseter"), which work them with proportionally greater force. The use of the small pincer-shaped incisor teeth is to gnaw the soft, gristly ends of the bones, and to tear and scrape off the tendinous attachments of the muscles and the periosteum. The compressed trenchant blades of the sectorial teeth play vertically upon each others' sides, like the blades of scissors, serving to cut and coarsely divide the flesh; and the form of the joint of the lower jaw almost restricts its movement to the vertical direction, up and down. The wide and deep zygomatic arches and the high crests of bone upon the skull concur in completing the carnivorous physiognomy of this most formidable of the feline tribe.

The dentition of the hyæna assumes those characteristics which adapt it for the peculiar food and habits of the adult. The main modification is the great size and strength of the molars as compared with the canines, and more especially the thick and strong conical crowns of the second and third premolars in both jaws, the base of the cone being belted by a strong ridge which defends the subjacent gum. This form of tooth is especially adapted for gnawing and breaking bones, and the whole cranium has its shape modified which work the jaws and teeth in this operation.

The strength of the hyæna's jaw is such that, in attacking a dog, he begins by biting off his leg at a single snap. Adapted, however, to obtain its food from the coarser parts of animals which are left by the nobler beasts of prey, the hyæna chiefly seeks the dead carcass, and bears the same relation to the lion which the vulture does to the eagle. The hyæna cracks, crushes, and devours the bones as well as the softer parts of the animals it preys upon. In consequence of the quantity of bones which enter into its food, the excrements consist of solid balls of a yellowish-white colour, and of a compact earthy fracture. Such specimens of the substance, known in the old "Materia Medica" by the name of "album græcum," were discovered by Dr. Buckland in the celebrated ossiferous cavern at Kirkdale. They were recognised at first sight by the keeper of a menagerie, to whom they were shown, as resembling both in form and appearance the fæces of the spotted hyæna; and, being analyzed by Dr. Wollaston, were found to be composed of the ingredients that might be expected in fæcal matter derived from bones—viz., phosphate of lime, carbonate of lime, and a very small proportion of the triple phosphate of ammonia and magnesia. This discovery of the coprolites of the hyæna formed, perhaps, the strongest of the links in that chain of evidence by which Dr. Buckland proved that the cave at Kirkdale, in Yorkshire, had been, during a long succession of years, inhabited as a den by hyænas, and that they dragged into its recesses the other animal bodies, whose remains, splintered, and bearing marks of teeth of the hyæna, were found mixed indiscriminately with their own.

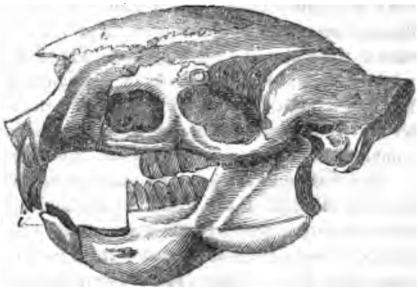
Fig. 18.



SKULL AND TEETH OF THE MORSE.

Before quitting the carnivorous order, the peculiar development of the upper canines of the morse or walrus deserve to be noticed. The staple food of this large modified seal is shell-fish, crustaceans, and sea-weed, which are pounded to a pulp by its small, obtuse molar teeth. The canines (Fig. 18), *c*, exist only in the upper jaw, where they are imbedded in deep and large prominent sockets, whence they sweep down, slightly incurved, forming large and long tusks, which serve as weapons of attack and defence, and as instruments in aid of climbing the floes and hummocks of ice, amongst which the walrus passes its existence.

Fig. 19.



SKULL AND TEETH OF A PORCUPINE.

In the order of mammalia, called gnawers or rodents, some of which, *e. g.*, the rat, are mixed feeders, but most of them herbivorous, the canine teeth are wanting in both jaws, and the incisors, reduced to two in number, are the seat of that excessive and uninterrupted growth, which makes them allied to tusks.

These incisors (Fig. 19), *i*, are curved the upper pair describing a larger part of a smaller circle, the lower ones a smaller part of a larger circle, the latter being the longest, and usually having their sockets extending from the fore to the back part of the under jaw. The tooth consists of a body of compact dentine, with a plate of enamel laid upon its anterior or convex surface, and the enamel commonly consists of two layers, of which the anterior and external one is the densest. Thus the substances of the incisor diminish in hardness from the front to the back part of the tooth. The wear and tear from the reciprocal action of the upper and lower incisors produce, accordingly, an oblique surface, sloping from a sharp anterior margin formed by the denser enamel, like that which, in a chisel, slopes from the sharp edge formed by the plate of hard steel laid on the back of that tool, whence these teeth have been called "chisel-teeth" (*dentes scalprarii*). Their growth never ceases while the animal lives, and the implanted part retains the form and size of the exposed part, and ends behind in a widely open or hollow base, which contains a long, conical, persistent forming pulp. This law of unlimited growth is unconditional, and constant exercise and abrasion are required to maintain the normal form and serviceable proportions of the scalpriform teeth of the rodents. When, by accident, an opposing incisor is lost, or when, by the distorted union of a broken jaw, the lower incisors no longer meet the upper ones, as sometimes happens to a wounded hare or rabbit, the incisors continue to grow until they project, like the tusks of the elephant, and the extremities, in the poor animal's attempts to acquire food, also become pointed like tusks. Following the curve prescribed to their growth by the form of their socket, their points often return against some part of the head, are passed through the skin, cause absorption of the bone, and perhaps again enter the mouth, rendering mastication impracticable, and causing death by starvation. In the Museum of the College of Surgeons there is a lower jaw of a beaver, in which the scalpriform incisor has, by unchecked growth, described a complete circle; the point has pierced the masseter muscle, entered the back of the mouth, and terminated close to the bottom of the socket containing its own hollow root.

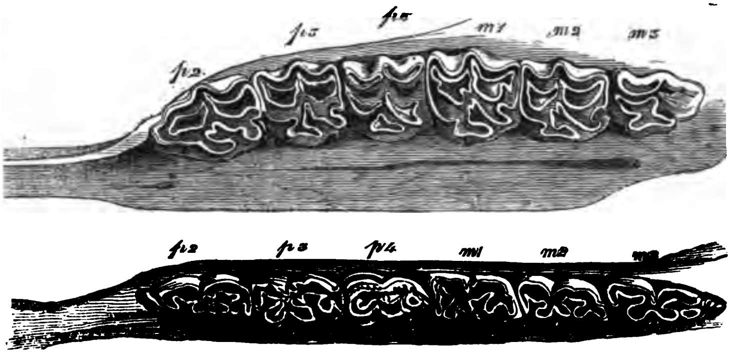
The difference in the diet of the rodent quadrupeds has been alluded to; there is a corresponding difference in the mode of implantation of their molar teeth. Those which subsist on mixed food, and which, like the rats, betray a tendency to carnivorous habits, or which subsist, like squirrels, on the softer and more nutritious vegetable substances, as the kernels of nuts, suffer less rapid abrasion of the grinding teeth; a less depth of crown is, therefore, needed to perform the office of mastication during the brief period of life allotted to these active little mammals; and, as the economy of nature is manifested in the smallest particulars as well as in her grandest operations, no more dental substance is developed after the crown is formed than is requisite for the firm fixation of the tooth in the jaw.

The rodents that exclusively subsist on vegetable substances, especially of the coarser and less nutritious kinds, as herbage, foliage, and the bark and wood of trees, wear away more rapidly the grinding surface of the molar teeth; the crowns are, therefore, larger, and their growth continues by a reproduction of the formative matrix at their base in proportion as its calcified constituents, forming the working part of the tooth, are worn away. So long as this reproductive force is active, the molar tooth is implanted, like the incisor, by a long, undivided continuation of the crown. These rootless and perpetually growing molars are always more or less curved, for they derive from this form the same advantage as the incisors, in the relief of the delicate tissues of the active vascular matrix from the effects of the pressure which would otherwise have been transmitted more directly from the grinding surface; the capybara, and the Patagonian hare (*Dolichotis*), afford good examples of this more complex condition of the grinding teeth.

The variety in the pattern of the folds of enamel that penetrate the substance of the tooth, and add to its triturating power, is almost endless; but the folds have always a tendency to a transverse direction across the crown of the tooth in the rodents. This direction relates to the shape of the joint of the lower jaw, which almost restricts it to horizontal movements to and fro, during the act of mastication. In the true hoofed herbivorous animals, in which the joint of the lower jaw allows a free rotatory movement, the folds of enamel take other forms and directions, with modifications, constant in each genus, and characteristic of such.

The horse is here selected as an example of such herbivorous dentition (Fig. 20). The grinding teeth are six in number, on each side of both upper and lower jaws, with thick square crowns of great length, and deeply implanted in the sockets, those of the upper jaw being slightly curved. When the summits or exposed ends of these teeth begin to be worn down by mastication, the interblended enamel, dentine, and cement

Fig. 20.



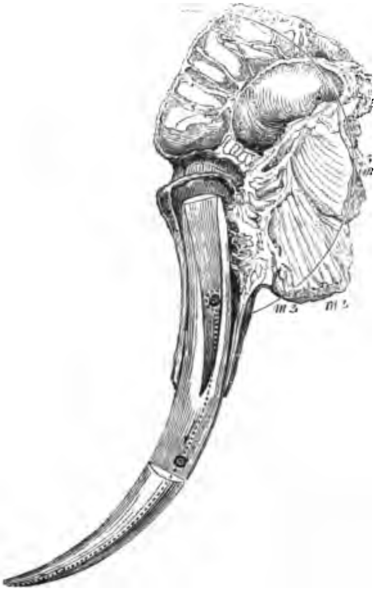
GRINDING SURFACES OF THE UPPER AND LOWER MOLARS OF A HORSE.

show the pattern figured in Cut 20; it is penetrated from within by a valley, entering obliquely from behind forwards, and dividing into or crossed by the two crescentic valleys, which soon become insulated. There is a large lobe at the end of the valley. The outer surface of the crown is impressed by two deep longitudinal channels. In the lower jaw the teeth are narrower transversely than in the upper jaw, and are divided externally into two convex lobes, by a median longitudinal fissure; internally they present three principal unequal convex ridges, and an anterior and posterior narrower ridge. All the valleys, fissures, and folds in both upper and lower grinders are lined by enamel, which also coats the whole exterior surface of the crown. Of the series of six teeth in each jaw, the first three, *p* 2, 3, 4, are premolars, the rest, *m* 1, 2, 3, are true molars.

The canines are small in the horse, and are rudimental in the mare; the unworn crown is remarkable for the folding in of the anterior and posterior margins of enamel. The upper canine is situated in the middle of the long interspace between the incisors and molars; the lower canine is close to the outer incisor, but is distinguished by its more pointed form. The incisors are six in number in both jaws; they are arranged close together in a curve, at the end of the jaw; the crown is broad, and the contour of the biting surface, before it is much worn, approaches an ellipse. The incisors of the horse are distinguished from those of ruminants by their greater length and curvature, and from those of all other animals by the fold of enamel (Fig. 3), *a*, which penetrates the crown from its flat summit, like the inverted finger of a glove. When the tooth begins to be worn, the fold becomes an island of enamel, inclosing a cavity partly filled by cement, and partly by the substances of the food, and is called the "mark." In aged horses the incisors are worn down below the extent of the fold, and the "mark" disappears. This cavity is usually obliterated in the first or mid incisors at the sixth year, in the second incisors at the seventh year, and in the third or outer incisors at the eighth year, in the lower jaw. The mark remains somewhat longer in the incisors of the upper jaw.

The following is the average course of development and succession of the teeth in the horse (*Equus caballus*):—The summits of the first functional deciduous molar, *d* 2, "first grinder" of veterinary authors, are usually apparent at birth; the succeeding grinder, *d* 3, sometimes arises a day or two later, sometimes together with the first. Their appearance is speedily followed by that of the first deciduous incisor—"centre nipper" of veterinarians—which usually cuts the gum between the third and sixth days. The second deciduous incisor appears between the twentieth and fortieth days, and about this time the rudimental grinder, *p* 1, comes into place, and the last deciduous molar, *d* 4, begins to cut the gum; about the sixth month the inferior lateral, or third incisors, with the deciduous canine, make their appearance. The minute canine is shed about the time that the contiguous incisor is in place, and is not retained beyond the first year. The upper deciduous canine is shed in the course of the second year. The first true molar, *m* 1, appears between the eleventh and thirteenth months. The second molar follows before the twentieth month. The first functional premolar, *p* 2, displaces the deciduous molar, *d* 2, at from two years to two years and a half old. The first permanent incisor protrudes from the gum at between two years and a half and three years. At the same period, the penultimate premolar, *p* 3, pushes out the penultimate milk molar, *d* 3, and the penultimate true molar comes into place. The last premolar displaces the last deciduous molar at between three years and a half and four years; the appearance above the gum of the last true molar, *m* 3, is usually somewhat earlier. The second incisor pushes out its deciduous predecessor about the same period. The permanent canine, or "tusk," next follows; its appearance indicates the age of four years, but it sometimes comes earlier. The third, or outer incisor, pushes out the deciduous incisor about the fifth year, but is seldom in full place before the horse is five and a half years old. Upon the rising of the third permanent incisor, or "corner nipper" of the veterinarians, the "colt" becomes a "horse," and the "filly," a "mare," in the language of the horse-dealer. After the disappearance of the "mark" in the incisors, at the eighth or ninth year the horse becomes "aged."

Fig. 21.



SECTION OF SKULL AND TEETH OF ELEPHANT.

The most complex condition of teeth adapted to a vegetable diet is that presented by the elephant. The dentition of the genus *Elephas* includes two long tusks (Fig. 21), one in each of the intermaxillary bones, and large and complex molars (*ib.*), *m* 3, 4, and 5, in both jaws; of the latter there is never more than one wholly, or two partially, in place and use on each side at any given time, for the series is continually in progress of formation and destruction, of shedding and replacement;

and all the grinders succeed one another, like true molars, horizontally, from behind forward.

The total number of teeth developed in the elephant appears to be $i\frac{2-2}{0-0}, m\frac{7-7}{7-7}=32$, the two large permanent incisors being preceded by two small deciduous ones, and the number of molar teeth which follow one another on each side of both jaws being seven, or at least six, of which the last three may, by analogy, be regarded as answering to the true molars of other pachyderms.

The incisors not only surpass other teeth in size, as belonging to a quadruped so enormous, but they are the largest of all teeth in proportion to the size of the body, representing, in a natural state, those monstrous tusks of the rodents, which are the result of accidental suppression of the wearing force of the opposite teeth.

The tusks of the elephant consist chiefly of that modification of dentine that is called "ivory," and which shows, on transverse fractures or sections, striæ proceeding in the arc of a circle from the centre to the circumference, in opposite directions, and forming by their decussations curvilinear lozenges. This character is peculiar to the tusks of the proboscidian pachyderms.

In the Indian elephant the tusks are always short and straight in the female, and less deeply implanted than in the male; she thus retaining, as usual, more of the characters of the immature state. In the male they have been known to acquire a length of nine feet, with a basal diameter of eight inches, and to weigh one hundred and fifty pounds; but these dimensions are rare in the Asiatic species.

A mammoth's tusk has been dredged up off Dungeness which measured eleven feet in length.* In several of the instances of mammoth's tusks from British strata, the ivory has been so little altered as to be fit for the purposes of manufacture; and the tusks of the mammoth, which are still better preserved in the frozen drift of Siberia, have long been collected in great numbers as articles of commerce. In the account of the mammoth's bones and teeth of Siberia, published in the "Philosophical Transactions" for 1737, No. 446, tusks are cited which weighed two hundred pounds each, and "are used as ivory, to make combs, boxes, and such other things, being but little more brittle, and easily turning yellow by weather and heat." From that time to the present there has been no intermission in the supply of ivory, furnished by the tusks of the extinct elephants of a former world.

The musket-balls and other foreign bodies which are occasionally found in ivory, are immediately surrounded by osteo-dentine in greater or less quantity. It has often been a matter of wonder how such bodies should become completely imbedded in the substance of the tusk, sometimes without any visible aperture, or how leaden bullets may have become lodged in the solid centre of a very large tusk without having been flattened. The explanation is as follows:—a musket ball, aimed at the head of an elephant, may penetrate the thin bony socket and the thinner ivory parietes of the wide conical pulp-cavity occupying the inserted base of the tusk; if the projectile force be there spent, the ball will gravitate to the opposite and lower side of the pulp-cavity, as indicated in Fig. 21. The presence of the foreign body exciting inflammation of the pulp, an irregular course of calcification ensues, which results in the deposition around the ball of a certain thickness of osteo-dentine. The pulp then resuming its healthy state and functions, coats the surface of the osteo-dentine inclosing the ball, together with the rest of the conical cavity into which that mass projects, with layers of normal ivory.

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* Owen's "History of British Fossil Mammalia," 8vo, 1844, p 244.

The portions of the cement-forming capsule surrounding the base of the tusk, and the part of the pulp, which were perforated by the ball in its passage, are soon replaced by the active reparative power of these highly vascular bodies. The hole formed by the ball in the base of the tusk is then more or less completely filled up by a thick coat of cement from without, and of osteo-dentine from within.

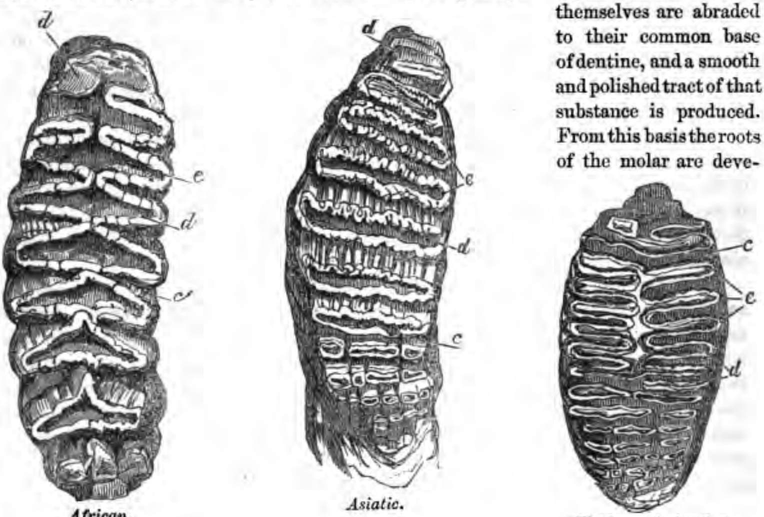
By the continued progress of growth, the ball so inclosed is carried forwards, in the course indicated by the arrow in Fig. 21, to the middle of the solidified exserted part of the tusk. Should the ball have penetrated the base of the tusk of a young elephant, it may be carried forwards by the uninterrupted growth and wear of the tusk, until that base has become the apex, and be finally exposed and discharged by the continual abrasion to which the apex of the tusk is subjected.

I had the tusk and pulp of the great elephant at the Zoological Gardens longitudinally divided, soon after the death of that animal in the summer of 1847. Although the pulp could be easily detached from the inner surface of the pulp-cavity, it was not without a certain resistance; and when the edges of the co-adapted pulp and tooth were examined by a strong lens, the filamentary processes from the outer surface of the pulp could be seen stretching as they were withdrawn from the dentinal tubes before they broke. They are so minute that, to the naked eye, the detached surface of the pulp seems to be entire, and Cuvier was thus deceived in concluding that there was no organic connection between the pulp and the ivory.

The molar teeth of the elephant are remarkable for their great size, even in relation to the bulk of the animal, and for the extreme complexity of their structure. The crown, of which a great proportion is buried in the socket, and very little more than the grinding surface appears above the gum, is deeply divided into a number of transverse perpendicular plates, consisting each of a body of dentine, coated by a layer of enamel, *e*, and this again by the less dense bone-like substance, *c*, which fills the interspaces of the enamelled plates, and here more especially merits the name of "cement," since it binds together the several divisions of the crown before they are fully formed and united by the confluence of their bases into a common body of dentine. As the growth of each plate begins at the summit, they remain detached, and like so many separate teeth or denticules, until their base is completed, when it becomes blended with the bases of contiguous plates to form the common body of the crown of the complex tooth, from which the roots are next developed.

The plates of the molar teeth of the Siberian mammoth (*Elephas primigenius*), (Fig. 22), are thinner in proportion to their breadth, and are generally a little expanded at the middle: and they are more numerous in proportion to the size of the crown than in the existing species of Asiatic elephant (*ib.*) In the African elephant (*ib.*), on the other hand, the lamellar divisions of the crown are fewer and thicker, and they expand more uniformly from the margins to the centre, yielding a lozenge-form when cut or worn transversely, as in mastication.

The formation of each grinder begins with the summits of the anterior plate, and the rest are completed in succession; the tooth is gradually advanced in position as its growth proceeds; and in the existing Indian elephant the anterior plates are brought into use before the posterior ones are formed. When the complex molar cuts the gum, the cement is first rubbed off the digital summits; then their enamel cap is worn away, and the central dentine comes into play with a prominent enamel ring; the digital processes are next ground down to their common uniting base, and a transverse tract of dentine, with its wavy border of enamel, is exposed; finally, the transverse plates themselves are abraded to their common base of dentine, and a smooth and polished tract of that substance is produced. From this basis the roots of the molar are developed and increase in length to keep the worn crown on the grinding level, until the reproductive force is exhausted. When the whole extent of a grinder has successively come into play, its last part is reduced to a long fang supporting a smooth and polished field of dentine, with, perhaps, a few remnants of the bottom of the enamel folds at its hinder part. When the complex molar has been thus worn down to an uniform surface, it becomes useless as an instrument for grinding the coarse vegetable substances on which the elephant subsists; it is attacked by the absorbent action, and the wasted portion of the molar is finally shed.



African. *Asiatic.* *Elephas primigenius.*

Fig. 22.—MOLAR TEETH OF ELEPHANTS AND THE SIBERIAN MAMMOTH.

The grinding teeth of the elephant progressively increase in size, and in the number of lamellar divisions from the first to the last; they succeed each other from behind forwards, moving, not in a right line, but in the arc of a circle, shown by the curved line in Fig. 21. The position of the growing tooth in the closed alveolus, *m*, *5*, is almost at right angles with that in use, the grinding surface being at first directed backwards in the upper jaw, and forwards in the lower jaw, and brought by the revolving course into a horizontal line in both jaws, so that they oppose each other when developed for use. The imaginary pivot on which the grinders revolve is next their root in the upper jaw, and is next the grinding surface in the lower jaw; in both, towards the frontal surface of the skull. Viewing both upper and lower molars as one complex whole, subject to the same revolving movement, the section dividing such whole into upper and lower portion runs parallel to the curve described by the movement—the upper being the central portion, or that nearest the pivot; the lower, the peripheral portion. The grinding surface of the upper molars is consequently convex from behind forwards, and that of the lower molars concave; the upper molars are always broader than the lower ones.

The bony plate forming the sockets of the growing teeth is more than usually distinct from the body of the maxillary, and participates in this revolving course, advancing forwards with the teeth.

Succession.—As the rate of increase, both of size and in the number of the component plates of the grinding tooth, is nearly identical in both jaws, it will suffice to briefly describe the teeth and the periods at which they successively appear in the lower jaw of the Asiatic elephant.

The *first molar*, which cuts the gum in the course of the second week after birth, has a sub-compressed crown, nine lines in antero-posterior diameter, divided by three transverse clefts into four plates, the third being the broadest, and the tooth here measuring six lines across; the base slightly contracts, and forms a neck as long as the enamelled crown, but of less breadth, and this divides into an anterior and posterior, long, sub-cylindrical, diverging, but mutually incurved fangs; the total length of this tooth is one inch and a half. The corresponding upper molar cuts the gum a little earlier than the lower one: the neck of this tooth is shorter, and the two fangs are shorter, larger, and more compressed than those of the lower first molar. The first molar of the elephant is the homologue of the probably deciduous molar (Fig. 25), *d* 2, in other ungulates; it is not a mere miniature of the great molars of the mature animal, but retains, agreeably with the period of life at which it is developed, a character much more nearly approaching that of the ordinary pachydermal molar, manifesting the adherence to the more general type by the minor complexity of the crown, and by the form and relative size of the fangs. In the transverse divisions of the crown we perceive the affinity to the tapiroid type, the different links connecting which with the typical elephants are supplied by the extinct lophiodons, dinotheriums, and mastodons. The subdivision of the summits of the primary plates recalls the character of the molars, especially the smaller ones, of the phacochere in the hog tribe. As the elephant advances in age the molars rapidly acquire their more special and complex character.

The first molars are completely in place and in full use at three months, and are shed when the elephant is about two years old.

The sudden increase and rapid development of the *second molar* may account for the non-existence of any vertical successor, or "premolar," to the former tooth, in the elephant. The eight or nine plates of the crown are formed in the closed alveolus, behind the first molar by the time this cuts the gum, and they are united with the body of the tooth, and most of them in use, when the first molar is shed. The average length of the second molar is two inches and a half, ranging from two inches to two inches and nine lines. The greatest breadth, which is behind the middle of the tooth, is from one inch to one inch three lines. There are two roots; the cavity of the small anterior one expands in the crown, and is continued into that of the three anterior plates. The thicker root supports the rest of the tooth. The second molar is worn out and shed before the beginning of the sixth year.

The *third molar* has the crown divided into from eleven to thirteen plates; it averages four inches in length, and two inches in breadth, and has a small anterior, and a very large posterior root; it begins to appear above the gum about the end of the second year, is in its most complete state and extensive use during the fifth year, and is worn out and shed in the ninth year. The last remnant of the third molar is shown at *m* 3 (Fig. 21). It is probable that the three preceding teeth are analogous to the deciduous molars, *d* 2, *d* 3, and *d* 4, in the hog (Fig. 25).

The *fourth molar* presents a marked superiority of size over the third, and a somewhat different form; the anterior angle is more obliquely abraded, giving a pentagonal figure to the tooth in the upper jaw (Fig. 21), *m* 4. The number of plates in the crown of this tooth is fifteen or sixteen, its length between seven and eight inches, its breadth three inches. It has an anterior simple and slender root supporting the three first plates, a second of larger size and bifid, supporting the four next plates, and a large contracting base for the remainder. The fore-part of the grinding surface of this tooth begins to protrude through the gum at the sixth year; the tooth is worn away, and its last remnant shed, about the twentieth or twenty-fifth year. It may be regarded as the homologue of the first true molar of ordinary pachyderms (Fig. 25), *m* 1.

The *fifth molar*, with a crown of from seventeen to twenty plates, measures between nine and ten inches in length, and about three inches and a half in breadth. The second root is more distinctly separated from the first simple root than from the large mass behind. It begins to appear above the gum about the twentieth year; its duration has not been ascertained by observation, but it probably is not shed before the sixtieth year.

The *sixth molar* is the last, and has from twenty-two to twenty-seven plates; its length, or antero-posterior extent, following the curvature, is from twelve to fifteen inches; the breadth of the grinding surface rarely exceeds three inches and a half. One may reasonably conjecture that the sixth molar of the Indian elephant, if it make its appearance about the fiftieth year, would, from its superior depth and length, continue to do the work of mastication until the ponderous pachyderm had passed the century of its existence.

Development.—The long-mistaken phenomena of the formation of the dental substances will be here described as they have been observed in the large teeth of the elephant; if the description be comprehended in regard to these, the most complex, members of the dental system, the true theory of dental development will be readily understood in regard to all the various forms and gradations of teeth. The matrix, or formative organ of the tusk, consists of a large conical pulp, which is renewed quicker than it is converted, and thus is not only preserved, but grows, up to a certain period of the animal's life; it is lodged in the cavity at the base of the tusk; this base is surrounded by the remains of the capsule, a soft vascular membrane of moderate thickness, which is confluent with the border of the base of the pulp, where it receives its principal vessels.

Each molar of the elephant is formed in the interior of a membranous sac—the capsule, the form of which partakes of that of the future tooth, being cubical in the first molar, oblong in the last, and rhomboidal in most of the intermediate teeth; but always decreasing in vertical extent towards its posterior end, and closed at all points, save where it is penetrated by vessels and nerves. It is lodged in an osseous cavity of the same form as itself, and usually in part suspended freely in the maxillary bone, the bony case being destined to form part of the socket of the tooth. The exterior of the membranous capsule is simple and vascular, as shown at *m* 5, Fig. 21; its internal surface gives attachment to numerous folds or processes, as in most other ungulate animals.

The dentinal pulp rises from the bottom of the capsule, or that part which lines the deepest part of the alveolus, in the form of transverse parallel plates extending towards that part of the capsule ready to escape from the socket. These plates adhere only to the bottom of the capsule; their opposite extremity is free from all adhesion. This summit is thinner than the base; it might be termed the edge of the plate; but it is notched, or divided into many digital processes. The tissue of these digitated plates is identical with that of the dentinal pulp of simple Mammalian teeth; it becomes also highly vascular at the parts where the formation of the dentine is in active progress.

Processes of the capsule descend from its summit into the interspaces of the dentinal pulp-plates, and consequently resemble them in form; but they adhere not only by their base to the surface of the capsule next the mouth, but also by their lateral margins to the sides of the capsule, and thus resemble partition-walls, confining each plate of the dentinal pulp to its proper chamber; the margin of the partition opposite its attached base is free in the interspace of the origins of the dentinal pulp-plates.

The enamel organ, which Cuvier appears to have recognised under the name of the internal layer of the capsule, is distinguishable by its light blue sub-transparent colour and usual microscopic texture, adhering to the free surface of the partitions formed by the true inner layer of the capsule. Although the enamel-pulp be in close contact with the dentinal pulp prior to the commencement of the formation of the tooth, one may readily conceive a vacuity between them, which is continued uninterruptedly, in many foldings, between all the gelatinous plates of the dentinal pulp, and the partitions formed by the combined enamel-pulp and the folds of the capsule. According to the excretion view, this delicate apparatus must have been immediately subjected to the violence of being compressed in the unyielding bony box, by the deposition of the dense matters of the tooth in the hypothetical vacuity between the enamel and dentinal pulps; a process of absorption must have been conceived to be set on foot immediately that the altered condition of the gelatinous secreting organs took place; and, according to Cuvier's hypothesis, the secreting function must be supposed to have proceeded, without any irregularity or interruption, while the process of absorption was superinduced in the same part to relieve it from the effects of pressure produced by its own secretion.

The formation of the dentine commences immediately beneath the *membrana propria* of the pulp; a part which Cuvier distinctly recognised, and which he accurately traced as preserving its relative situation between the dentine and enamel throughout the whole formation of the dentine, and discernible in the completed tooth "as a very fine grayish line, which separates the enamel from the internal substance" or dentine.

The calcification and conversion of the cells of the dentinal pulp commence as usual at the peripheral parts of the lamelliform processes furthest from the attached base. It may readily be conceived, therefore, that, at the commencement, there is formed a little cap upon each of the processes into which the edges of the pulp-plates are divided. As the centripetal calcification proceeds the caps are converted into horn-shaped cones. When it has reached the bottom of the notches of the edge of the pulp-plate all the cones become united together into a single transverse plate; and, the process of conversion having reached the base of the pulp-plate, these plates coalesce to form a common base to the crown of the tooth, which would then present the same eminences and notches that characterized the gelatinous pulp, if, during the period of conversion, other substances had not been formed upon the surface and in the interspaces of the pulp-plates.

Coincident, however, with the formation of the dentine, is the deposition of the hardening salts of the enamel in the extremely slender prismatic cells, which are for the most part vertical to the plane of the inner surface of the folds of the capsule to which they are attached. The true inner part of the capsule forms those thick transverse folds or partitions which support the enamel organ, and with it fill the interspaces of the dentinal pulps. With regard to the formation of the cement, Cuvier, after citing the opinion of Tenon—that it was the result of ossification of the internal layer of the capsule, and that of Blake—that it was a deposition from the opposite surface of the capsule to that which had deposited the enamel, states his own conviction to be that the cement is produced by the same layer and by the same surface as that which has produced the enamel. The proof alleged is, that so long as any space remains between the cement and the external capsule, that space is found to contain a soft internal layer of the capsule with a free surface next the cement. The phenomena could not, in fact, be otherwise explained according to the "excretion theory" of dental development. To the obvious objection that the same part is made, in this explanation, to secrete two different products, Cuvier replies, that it undergoes a change of tissue: "Whilst it yielded enamel only it was thin and transparent; to give cement it becomes thick, spongy, and of a reddish colour." The external characters of the enamel organ and cement-forming capsule are correctly defined; only, the one, instead of being converted into the other, is in fact changed into its supposed transudation; the enamel fibres being formed, and properly disposed in the direction in which their chief strength is to lie, by the assimilative properties of the pre-arranged elongated prismatic non-nucleated cells, which take from the surrounding plasma the required salts, and compact them in their interior.

Whilst this process is on foot, and before the enamel fibres are firm in their position, the capsule begins to undergo that change which results in the formation of the thick cement; the calcifying process commences from several points, and proceeds centrifugally, radiating therefrom, and differing from the ossification of bone chiefly in the number of these centres, which, though close to the new-formed enamel, are in the substance of the inner vascular surface of the capsular folds. The cells arrange themselves in concentric layers around the vessels, and act like those of the enamel pulp in receiving into their interior the bone-salts in a clear and compact state. During this process they become confluent with each other, their primitive distinctness being indicated only by their persistent granular nuclei, which now form the radiated Purkingian capsules. The interspaces of the concentric series of confluent cells become filled with the calcareous salts in a rather more opaque state, and the conversion of the capsule into cement goes on, according to the processes more particularly described in the Introduction to my "Odontography," until a continuous stratum is formed in close connection with the layer of enamel.

Calcification extending from the numerous centres, the different portions coalesce, and progressively add to the thickness of the cement, until all the interspaces of the coronal plates and the whole exterior of the crown are covered with the bone-like substance. The enamel-pulp ceases to be developed at the base of the crown, but the capsule continues to be formed *pari passu* with the partial formation of the pulp, as this continues, progressively contracting, from the base of the crown, to form, by its calcification, the roots. The calcification of the capsule going on at the same time, a layer of cement is formed in immediate connection with the dentine. The circumscribed spaces at the bottom of the socket to which the capsule and dentinal pulp adhere, where they receive their vessels and nerves, and which are the seat of the progressive formation of these respective moulds of the two dental tissues, become gradually contracted, and subdivided by the further localization of the reproductive forces to particular spots, whence the subdivision of the base into roots. The surrounding bone undergoes corresponding modifications, growing and filling up the interspaces left by the dividing and contracting points of attachment of the residuary matrix. All is subordinated to one harmonious law of growth by vascular action and cell-formation, and of molecular decrement by absorption. Mechanical squeezing, or drawing out, has no share in these changes of the pulp or capsule; pressure at most exercises only a gentle stimulus to the vital processes. Cuvier believed that there were places where the dentinal pulp and the capsule were separate from each other. I have never found such, except where the enamel-pulp was interposed between them in the crown of the tooth, or where both pulp and capsule adhered to the periosteum of the socket, below the crown. Cuvier affirms that the number of fangs of an elephant's molar depends upon the number of points at which the base of the gelatinous (dentinal) pulp is attached to the bottom of the capsule; and that the interspaces of these attachments constitute the under part of the crown or body of the tooth, the attachments themselves forming the first beginnings of the fangs. True to his hypothesis of the formation of the dental tissues by excretion, he says that the elongation of the fangs is produced by two circumstances: first, the progressive elongation of the layers of osseous substance (dentine) which force the tooth to rise and emerge from its socket; secondly, the thickening of the body of the tooth by the addition of successive layers to its inner surface, which, filling up the interior cavity, leaves scarcely room for the gelatinous pulp, and forces it down into the interior of the roots.

This pulling up of the fang on the one hand, and squeezing down the pulp on the other, are forces too gross and mechanical to be admitted in actual physiology to explain the growth of the root of a tooth or of any other organized product; such modes of explanation were, however, inevitable in adopting the "excretion theory" of dental development.

There are few examples of organs that manifest a more striking adaptation of a highly complex and beautiful structure to the exigencies of the animal endowed with it, than the grinding teeth of the elephant. We perceive, for example, that the jaw is not encumbered with the whole weight of the massive tooth at once, but that it is formed by degrees as it is required; the division of the crown into a number of successive plates, and the subdivision of these into cylindrical processes, presenting the conditions most favourable to progressive formation. But a more important advantage is gained by this subdivision of the tooth; each part is formed like a perfect simple tooth, having a body of dentine, a coat of enamel, and an outer investment of cement. A single digital process may be compared to the simple canine of a carnivore; a transverse row of these, therefore, when the work of mastication has commenced, presents, by virtue of the different densities of their constituent substances, a series of cylindrical ridges of enamel, with as many depressions of dentine, and deeper external valleys of cement; the more advanced and more abraded part of the crown is traversed by the transverse ridges of the enamel inclosing the depressed surface of the dentine, and separated by the deeper channels of cement: the fore part of the tooth exhibits its least efficient condition for mastication, the inequalities of the grinding surface being reduced, in proportion as the enamel and cement have been worn away. This part of the tooth is, however, still fitted for the first coarse crushing of the branches of a tree: the transverse enamel ridges of the succeeding part of the tooth divide it into smaller fragments, and the posterior islands and tubercles of enamel pound it to the pulp fit for deglutition.

The structure and progressive development of the tooth not only give to the elephant's grinder the advantage of the uneven surface which adapts the millstone for its office, but, at the same time, secure the constant presence of the most efficient arrangement for the finer comminution of the food, at the part of the mouth which is nearest the fauces.

In the tusks of the *Mastodon giganteus* the outer layer of cement is relatively thicker than in the tusks of the mammoth, or in those of the Indian elephant. The general character of the microscopic structure of the ivory of the mastodon's tusk is the same as that of the elephant.

By the minuteness and close arrangement of the dentinal tubes, and especially by their strongly undulating secondary curves, a tougher and more elastic tissue is produced than results from their disposition in ordinary dentine; and the modification which distinguishes "ivory" is doubtless essential to the due degree of coherence of so large a mass as the elephant's tusk, projecting so far from the supporting socket; and to be frequently applied in dealing hard blows and thrusts.

Teeth of the Megatherium.—The megatherium (Gr. *megas*, great; *therion*, beast), so called from its colossal size—being as large as the elephant, and even surpassing that hugest of existing quadrupeds in some of its proportions—was once an inhabitant, and apparently in some numbers, of the American continent, especially its southern division, and subsisted on a similar kind of food to the elephants, viz., the smaller branches and leaves of trees; but all the genera and species of megatherioid beasts are now extinct. Nevertheless, from the fossil remains of the megatherium the anatomist is able unerringly to deduce the nature of its food and many of its peculiar habits; and also to bring to light a system of dentition, designed, like that of the elephants, for the service of crushing and masticating a coarse vegetable diet throughout a long-protracted individual existence; and yet, by a modification of the formative processes and economy of the teeth, quite different from those that have been adopted for the same ends in the elephant tribe.

In these, as has been shown, the supply of a masticating apparatus, to serve the requirements of a gigantic animal during one or perhaps two centuries of existence, was provided by a succession of *different* molar teeth presenting the due complexity of structure. In the megatherium the same end was obtained by a perpetual growth of the *same* complex molar teeth—the different dental substances being formed at and added to the base of the tooth, in proportion as they were ground down at the exposed summit.

The true number of teeth was determined by a removal of the mineral substances adhering to the surface of a portion of a fossil skull of a megatherium, brought by Mr. Charles Darwin from South America (Fossil Mammalia of the "Voyage of the Beagle," 4to, 1840, p. 102). The animal has not, as in the elephant, any tusks: its teeth are molars or grinders exclusively; they are five in number on each side of the upper jaw, and four on each side of the lower jaw—eighteen in all. All these teeth are remarkable for their great length in proportion to their breadth or thickness, being from eight to ten inches in length, and between two and three inches only in breadth. They are very deeply implanted in the jaw, and the lower jaw has a quite peculiar form, in order to acquire the requisite room for the lodgment of the lower teeth and their "matrices," or formative organs.

The next peculiarity to be noticed in these remarkable teeth is the great length of the conical cavity at their base, for lodging the part of the matrix called the "pulp;" the apex of the pulp-cavity rising as far as the part of the tooth where it emerges from the socket. A transverse fissure is continued from this apex to the middle concavity of the grinding surface of the tooth, which is thus divided into two halves. Each of these halves consists of three distinct substances—a central column of "vaso-dentine," a peripheral and nearly equally thick layer of "cement," and an intermediate thinner stratum of true or "hard dentine." This latter has been described as being enamel; but it is only analogous to that differently constituted and harder substance in the compound teeth of the elephant, in regard to its relative situation, and its degree of density to the other constituents of the tooth of the megatherium.

No species of the order called "Bruta" or "Edentata," to which the extinct megatherium belongs, has true enamel entering into the composition of its teeth; but the modifications of structure which the teeth present in the different genera of this order are considerable, and their complexity is not less than that of the enamelled teeth of the herbivorous, ruminant, and other hoofed animals, in consequence of the introduction of a dental substance—the "vaso-dentine"—into their composition, analogous in structure to that of the teeth of the *Myliobates* and other cartilaginous fishes. The cement of the megatherium's tooth differs from the vaso-dentine in the larger size and wider interspaces of its medullary canals, and by the presence of radiated bone-cells in their interspaces; but they are brought into organic communication with each other, not only by means of the tubes of coarse dentine, but by occasional continuity of the vascular canals across that substance. The tooth of the megatherium thus offers an unequivocal example of a course of nutriment from the dentine to the cement, and reciprocally; so that the main substance or body of the tooth can obtain the requisite supply for its languid vitality from the vessels of the capsule as well as from those of the pulp.

The conical cavity at the base of the tooth attests the large size, and demonstrates the form of the persistent pulp in the living megatherium: the diameter of its base is equal to the part of the tooth which is formed by the combined dentine and vaso-dentine. From the gradual thinning off and final disappearance of those substances as they reach the base of the tooth, it may be inferred that both were formed at the expense of the pulp. The fine dentinal tubes must have been established and calcified in the peripheral layer of the pulp, which layer must have been wholly so converted into the dentine; but as the deposition of the hardening salts proceeded in the rest of the pulp, certain tracts of that soft and vascular substance were left uncalcified, to form the medullary or vascular canals which characterize the vaso-dentine. The space between the inserted base of the tooth and the walls of the socket indicates the thickness of the dental capsule, by the ossification of which the exterior layer of cement was formed; and this modification of the tooth-forming organ in the megatherium permitted the progressive addition of cement, as the persistence of the compound pulp occasioned the uninterrupted and continuous formation of the harder dentine, which is analogous to the enamel in the elephant's grinder.

In all essential characters the teeth of the megatherium repeat, on a magnified scale, the dental peculiarities of the sloth; and since, from a similarity of the form, number, kinds, and structure of teeth, a similarity of food is to be inferred, it may be concluded that the leaves and soft succulent sprouts of trees formed the staple diet of the megatherium, and of the cognate and contemporary megalonyx and mylodon, as of the existing sloths. The enormous claws of those great extinct sloth-like quadrupeds, to judge by the fossorial (digging and scratching) character of the powerful mechanism of the limbs that worked them, were employed, not, as in the sloths, to carry the animal to its food, but to bring the food within the reach of the animal, by uprooting the trees on which it grew.

In the remains of the megatherium we have evidence of the framework of a quadruped equal to the task of undermining and tearing down the largest trees in a tropical forest. In the latter operation it is obvious that the immediate application of the anterior extremities to the trunk of the tree would demand a corresponding fulcrum to be effectual; and it is the necessity for an adequate basis of support and resistance to such an application of the fore-extremities which gives the explanation of the seemingly anomalous development of the pelvis, tail, and hinder extremities of the megatherium and its extinct allies. No wonder, therefore, that their type of structure should be so peculiar; for where shall we now find quadrupeds equal, like them, to the habitual task of uprooting trees for food!

Teeth of the Anoplotherium.—Of the extinct quadrupeds with hoofs, and which were consequently herbivorous, the species restored by Cuvier from fossil remains discovered in the quarries at Montmartre, near Paris, was one of the most ancient. The great comparative anatomist called it *anoplotherium*, from the Greek words signifying "weaponless," because it had neither horns nor tusks. It was, however, characterized by the most complete system of dentition; for it not only possessed incisors and canines in both jaws, but these were so equably developed that they formed one unbroken series with the premolars and molars, which character is now found only in the human species.

The dental formula of the genus *Anoplotherium* is expressed by—$i\frac{3-3}{3-3}$, $c\frac{1-1}{1-1}$, $p\frac{4-4}{4-4}$, $m\frac{3-3}{3-3} = 44$, signifying that it had, on each side of both upper and lower jaws, three incisors, one canine, four premolars, and three true molars; in all, forty-four teeth.

Those teeth which are transitorily manifested in the embryo state of some ruminants, as the upper incisors and canines and the anterior premolars, *p* 1, were in the ancient anoplothere retained and raised to a proportional equality of size and function with the rest of the teeth. The true molars had a broad grinding surface, with enamel-covered crescentic lobes, remotely resembling those of the existing ruminants. In some of the smaller species of *anoplotherium* the ruminant type of grinding surface was more closely adhered to, and the fossil lower jaws of such species, as *e. g.* of the *Dichobune cervinum* have been mistaken for those of a ruminant, and have been referred to the genus *Moschus*. One of these interesting transitional extinct quadrupeds, described in the "Geological Journal," for 1847, under the name of *Dichodon*, had forty-four teeth in one uninterrupted series, and of the same kinds, as in the anoplothere; but the teeth there marked *p* 4, and *m* 1, upper jaw, I have ascertained to be "milk-teeth."

Teeth of Ruminants.—The even-toed or artiodactyle *Ungulata* superadd the characters of simplified form and diminished size to the more important and constant one of vertical succession in their premolar teeth. These teeth, in the ruminants, represent only the moiety of the true molars, or one of the two semi-cylindrical lobes of which those teeth consist, with at most a rudiment of the second lobe. An analogous morphological character of the premolars will be found to distinguish them in the dentition of the genus *Sus* (Fig. 25, *p* 2, *p* 3, *p* 4), in the hippopotamus and in the *phacochœrus* or wart-hog, where the premolar series is greatly reduced in number: yet this instance of a natural affinity, manifested in so many other parts of the organization of the artiodactyle genera, has been overlooked in F. Cuvier's work above cited, although it is expressly designed to show how such zoological relations are illustrated by the teeth.

Most of the deciduous teeth of the ruminants resemble in form the true molars; the last, *e. g.*, has three lobes in the lower jaw like the last true molar. When, therefore, the third grinder of the lower jaw of any new or rare ruminant shows three lobes, the crowns of the premolars should be sought for in the substance of the jaw below these, and above their opponents in the upper jaw; and thus the true characters of the permanent dentition may be ascertained.

The deciduous molars are three in number on each side, and, being succeeded by as many premolars, the ordinary permanent molar formula is $p\,\frac{3-3}{3-3},\ m\,\frac{3-3}{3-3}$: but there is a rudiment of an anterior milk-molar, *d* 1, in the embryo fallow-deer, and in one of the most ancient of the extinct ruminants (*dorcatherium*, Kaup) the normal number of premolars was fully developed.

The molar series of all the Diphyodonts is naturally divisible into only two groups, premolars and molars; the typical number of these is $\frac{4-4}{4-4},\ \frac{3-3}{3-3}$; and each individual tooth may be determined and symbolized throughout the series, as is shown in the instances under Cut 25.

Seal Tribe.—(*Phocidæ*).—There is a tendency to deviate from the ferine number of the incisors in the most aquatic and piscivorous of the Musteline quadrupeds, viz., the sea-otter (*enhydra*), in which species the two middle incisors of the lower jaw are not developed in the permanent dentition. In the family of true seals, the incisive formula is further reduced, in some species even to zero in the lower jaw, and it never exceeds $\frac{3-3}{2-2}$. All the *phocidæ* possess powerful canines; only in the aberrant walrus are they absent in the lower jaw; but this is compensated by the singular excess of development which they manifest in the upper jaw (Fig. 18). In the pinnigrade, as in the plantigrade, family of carnivores, we find the teeth which correspond to true molars more numerous than in the digitigrade species, and even occasionally rising to the typical number, three on each side; but this, in the seals, is manifested in the upper, and not, as in the bears, in the lower jaw. The entire molar series usually includes five, rarely six teeth on each side of the upper jaw, and five on each side of the lower jaw, with crowns, which vary little in size or form in the same individual; they are supported in some genera, as the eared seals (*otariæ*), and elephant seals (*cystophora*), by a single fang; in other genera by two fangs, which are usually connate in first or second teeth; the fang or fangs of both incisors, canines and molars, are always remarkable for their thickness, which commonly surpasses the longest diameter of the crown. The crowns are most commonly compressed, conical, more or less pointed; in a few of the largest species they are simple and obtuse, and particularly so in the walrus, in which the molar teeth are reduced to a smaller number than in the true seals. In these the line of demarcation between the true and false molars is very indefinitely indicated by characters of form or position; but, according to the instances in which a deciduous dentition has been observed, the first three permanent molars in both jaws succeed and displace the same number of milk molars, and are consequently *premolars;* occasionally, in the seals with two-rooted molars, the more simple character of the premolar teeth is manifested by their fangs being connate, and in the *Stenorhynchus serridens* the more complex character of the true molars is manifested in the crown. In the *Stenorhynchus leptonyx* each molar tooth in both jaws is trilobed, the anterior and posterior accessory curving towards the principal one, which is bent slightly backwards; all the divisions are sharp-pointed, and the crown of each molar thus resembles the trident or fishing-spear; the two fangs of the first molar in both jaws are connate. In the *Stenorhynchus serridens* the three anterior molars on each side of both jaws are four-lobed, there being one anterior and two posterior accessory lobes; the remaining posterior molars (true molars) are five-lobed, the principal cusp having one small lobe in front, and three developed from its posterior margin; the summits of the lobes are obtuse, and the posterior ones are recurved like the principal lobe. Sometimes the third molar below has three instead of two posterior accessory lobes. Occasionally, also, the second, as well as the first molar above, has its fangs connate: but the essentially duplex nature of the seemingly single fang, which is unfailingly manifested within by the double pulp-cavity, is always outwardly indicated by the median longitudinal opposite indentations of the implanted base.

Teeth of Quadrumana.—The chief aim of comparative anatomy being the better comprehension of the structure of man, we shall finally describe those modifications of the dental system which throw more immediate light on the nature of the teeth in the human subject, and which are met with, as might be expected, in the order (*Quadrumana*) of *mammalia* that makes the nearest approach to that represented by the genus *homo*.

Through a considerable part of the quadrumanous series, *e.g.*, in all the apes and monkeys of the Old World, in all the genera indeed which are above the lemurs (cat-monkeys and slow monkeys) of Madagascar, the same number and kinds of teeth are present as in man; the first deviation being the disproportionate size of the canines and the concomitant break or "diastema" in the dental series for the reception of their crowns when the mouth is shut. This is manifested in both the chimpanzees and orangs, together with a sexual difference in the proportions of the canine teeth.

In that large ape of tropical Africa, called the "gorilla" (*Troglodytes gorilla*), which in some important particulars more resembles man than does the smaller kind of chimpanzee (*Troglodytes niger*), the dentition seems to approach nearer to the carnivorous type, at least in the full-grown male (see Fig. 50, p. 261). It is nevertheless strictly quadrumanous in its essential characters, as in the broad, flat, tuberculate grinding surfaces of the molar teeth; but in the minor particulars in which it differs from the dentition of the orang, it approaches nearer the human type. In the upper jaw the middle incisors are smaller, the lateral ones larger than those of the orang; they are thus more nearly equal to each other; nevertheless the proportional superiority of the middle pair is much greater than in man, and the proportional size of the four incisors both to the entire skull and to the other teeth is greater. Each incisor has a prominent posterior basal ridge, and the outer angle of the lateral incisors, *i* 2, is rounded off as in the orang. The incisors incline forwards from the vertical line as much as in the great orang. The characteristics of the human incisors are, in addition to their true incisive wedge-like form, their near equality of size, their vertical or nearly vertical position, and small relative size to the other teeth and to the entire skull. The diastema, between the incisors and the canine on each side, is as well marked in the male chimpanzee as in the male orang. The crown of the canine (*ib.*), *c*, passing outside the interspace between the lower canine and premolar, extends, in the male *Troglodytes gorilla*, a little below the alveolar border of the under jaw when the mouth is shut: the canines in both jaws are twice the size of those teeth in the female gorilla.

Both premolars are bicuspid; the outer cusp of the first and the inner cusp of the second being the largest, and the first premolar consequently appearing the largest on an external view. The anterior external angle of the first premolar is not produced as in the orang, which in this respect makes a marked approach to the lower *quadrumana*. In man, where the outer curve of the premolar part of the dental series is greater than the inner one, the outer cusps of both premolars are the largest; the alternating superiority of size in the champanzee accords with the straight line which the canine and premolars form with the true molars.

The three true molars are quadricuspid, relatively larger in comparison with the bicuspids than in the orang. In the first and second molars of both species of chimpanzee a low ridge connects the antero-internal with the postero-external cusp, crossing the crown obliquely, as in man. There is a feeble indication of the same ridge in the unworn molars of the orang; but the four principal cusps are much less distinct, and the whole grinding surface is flatter and more wrinkled than in the chimpanzee. The repetition of the strong sigmoid curves, which the unworn prominences of the first and second true molars present in man, is a very significant indication of the near affinity of the gorilla and the chimpanzee, as compared with the approach made by the orangs or any of the inferior *quadrumana*, in which the four cusps of the true molars rise distinct and independently of each other. The premolars as well as molars are severally implanted by one internal and two external fangs, diverging, but curving towards each other at their ends as if grasping the substance of the jaw. In no variety of the human species are the premolars normally implanted by three fangs; at most the root is bifid, and the outer and inner divisions of the root are commonly connate. It is only in the black varieties, and more particularly that race inhabiting Australia, that I have found the wisdom tooth, or last true molar, with three fangs as a general rule; and the two outer ones are more or less confluent.

The molar series in both species of chimpanzee forms a straight line, with a slight tendency in the upper jaw to bend in the opposite direction to the well-marked curve which the same series describes in the human subject. This difference of arrangement, with the more complex implantation of the premolars, the proportionally larger size of the incisors as compared with the molars; the still greater relative magnitude of the canines; and, above all, the sexual distinction in that respect illustrated by the skull of the full-grown male gorilla (Fig. 50, p. 261), stamp the chimpanzees most decisively with not merely specific but generic distinctive characters as compared with man. For the teeth are fashioned in their shape and proportions in the dark recesses of their closed formative alveoli, and do not come into the sphere of operation of external modifying causes, until the full size of the crowns has been acquired. The formidable natural weapons, with which the Creator has armed the powerful males of both species of chimpanzee, form the compensation for the want of that psychical capacity to forge destructive instruments which has been reserved as the exclusive prerogative of man. Both chimpanzees and orangs differ from the human subject in the order of the development of the permanent series of teeth; the second molar, *m* 2, comes into place before either of the premolars has cut the gum, and the last molar, *m* 3, is acquired before the canine. We may well suppose that the larger grinders are earlier required by the frugivorous chimpanzees and orangs than by the higher organized omnivorous species with more numerous and varied resources, and probably one main condition of the earlier development of the canines and premolars in man may be their smaller relative size.

In the South American quadrumana the number of teeth is increased to thirty-six, by an addition of one tooth to the molar series on each side of both jaws. It might be concluded, *à priori*, that as three is the typical number of true molars in the placental mammalia with two sets of teeth, the additional tooth in the *cebinæ* would be a premolar, and form one step to the resumption of the normal number (four) of that kind of teeth. The proof of the accuracy of this inference is given by the state of the dentition in any young spider-monkey (*Ateles*), or Capucin-monkey (*Cebus*), which may correspond with that of the human child in Fig. 26, *i. e.*, where the whole of the deciduous dentition is retained, together with the first true molar (*m* 1) on each side of both jaws. If the germs of the other teeth of the permanent series be exposed in the upper jaw (as in Fig. 26), the crown of a premolar will be found above the third molar in place, as well as above the second and first. As regards number, therefore, the molar series, in the South American monkeys (*Mycetes*, *Ateles*, *Cebus*), is intermediate between that of the genus *Mustela* and of *Felis* (Fig. 17); the little premolar, *p i*, in *Mustela*, shows plainly enough which of the four is wanting to complete the typical number in the South American monkey, and which is the additional premolar distinguishing its dental formula from that of the Old World monkeys and man.

Zoologists have rightly stated, as a matter of fact, that the little marmoset monkeys (*Hapale*, *Ouistiti*) "have only the same number of teeth as the monkeys of the Old World—viz., 32, $i\,\frac{4}{4}$, $c\,\frac{1-1}{1-1}$, $m\,\frac{5-5}{5-5}$." But the difference is much greater than this numerical conformity would intimate. In a young *Jacchus penicillatus* I find that there are three deciduous molars displaced by three premolars, as in the other South American quadrumana, and that it is the last true molar, *m* 3, the development of which is suppressed, not the premolar, *p* 2, and thus these diminutive squirrel-like monkeys actually differ from the Old World forms more than the *Cebidæ* do; *i. e.*, they differ not only in having four teeth ($p\,2\,\frac{1-1}{1-1}$), which the monkeys of the Old World do not possess, but also by wanting four teeth ($m\,3\,\frac{1-1}{1-1}$), which those monkeys, as well as the *Cebidæ*, actually have. It is thus that the investigation of the exact homologies of parts leads to a recognition of the true characters indicative of zoological affinity.

Most of the *Lemurinæ* have $p\,\frac{3-3}{3-3}$, $m\,\frac{3-3}{3-3}$, together with remarkable modifications of their incisive and canine teeth, of which an extreme example is shown in the pectinated tooth of the *galeopithecus*. The inferior incisors slope forwards in all, and the canines also, which are contiguous to them, and very similar in shape.

In the hoofed quadrupeds with toes in uneven number (*perissodactyla*), whose premolars, for the most part, repeat both the form and the complex structure of the true molars, such premolars are distinguished by the same character of development as those of the *artiodactyla*, or ungulates, with toes in even number; although here the premolars are distinguished also by modifications of size and shape. The complex ridged and tuberculate crowns of the second, third, and fourth grinders of the rhinoceros, hyrax, and horse, no more prove them to be true molars than the trenchant shape of the lower carnassials of the lion proves them to be false molars. It is by development alone that the primary division of the series of grinding teeth can be established, and by that character only can the homologies of each individual tooth be determined, and its proper symbol applied to it.

In Fig. 20, the three posterior teeth of the almost uniform grinding series of the horse's dentition are thus proved to be the only ones entitled to the name of "true molars;" and, if any one should doubt the certainty of the rule of counting, by which the symbols, *p* 4, *p* 3, and *p* 2, are applied to the three large anterior grinding teeth (*ib.*), which are commonly the only premolars present in each lateral series of the horse's jaws, yet the occasional retention of the diminutive tooth (*p* 1), would establish its accuracy, whether such tooth be regarded as the first of the deciduous series unusually long retained, or the unusually small and speedily lost successor (*p* 1) of an abortive (*d* 1).

The law of development, so beautiful for its instructiveness and constancy in the placental *diphyodonts*, is well illustrated in the little hyrax, in which the *d* 1 is normally developed and succeeded by a permanent, *p* 1, differing from the rest only by a graduated inferiority of size, which, in regard to the last premolar, ceases to be a distinction between it and the first true molar.

The elephant, which by its digital characters belongs to the odd-toed, or perissodactyle, group of pachyderms, also resembles them in the close agreement in form and structure of the grinding teeth representing the premolars, with those that answer to the true molars of the hyrax, tapir, and rhinoceros. The gigantic proboscidian pachyderms of Asia and Africa present, however, so many peculiarities of structure as to have led to their being located in a particular family in the Systematic Mammalogies. And this seems to be justified by no character more than by the singular seeming exception which they present to the diphyodont rule which governs the dentition of other hoofed quadrupeds. In fact, the elephant, like the dugong, sheds and replaces vertically only its incisors, which are also two in number, very long, and of constant growth, forming tusks, with an analogous sexual difference in this respect in the female of the Asiatic species. The molars, also, are successively lost, are not vertically replaced, and are reduced finally to one on each side of both jaws, which is larger than any of its predecessors. These analogies are interesting and suggestive in connection with the other approximations in the "Sirenia" to the pachydermal type.

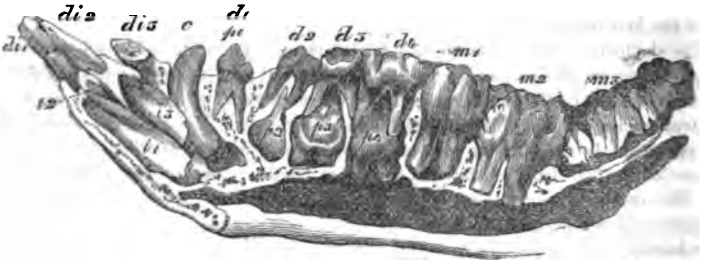
In the mammalian orders with two sets of teeth, these organs acquire fixed individual characters, receive special denominations, and can be determined from species to species. This individualization of the teeth is eminently significative of the high grade of organization of the animals manifesting it. Originally, indeed, the name "incisors," "laniaries" or "canines," and "molars" were given to the teeth, in man and certain mammals, as in reptiles, in reference merely to the shape and offices so indicated; but they are now used as arbitrary signs, in a more fixed and determinate sense. In some carnivora, *e. g.*, the front teeth have broad tuberculate summits, adapted for nipping and bruising, while the principal back teeth are shaped for cutting, and work upon each other like the blades of scissors. The front teeth in the elephant project from the upper jaw, in the form, size, and direction of long pointed horns. In short, shape and size are the least constant of dental characters in the mammalia; and the homologous teeth are determined, like other parts, by their relative position, by their connections, and by their development.

Those teeth which are implanted in the premaxillary bones, and in the corresponding part of the lower jaw, are called "incisors," whatever be their shape or size. The tooth in the maxillary bone, which is situated at, or near to, the suture with the premaxillary, is the "canine," as is also that tooth in the lower jaw which, in opposing it, passes in front of its crown when the mouth is closed. The other teeth of the first set are the "deciduous molars;" the teeth which displace and succeed them vertically are the "pre-molars;" the more posterior teeth, which are not displaced by vertical successors, are the "molars" properly so called.

The hog is one of the few existing quadrupeds which retain the typical number and kinds of teeth.

Figure 25, part of the lower jaw of a young hog, illustrates the phenomena of development which distinguishes the premolars from the molars. The first premolar, *p* 1, and the first molar, *m* 1, are in place and use, together with the three deciduous molars, *d* 2, *d* 3, and *d* 4; the second molar, *m* 2, has just begun to cut the gum; *p* 2, *p* 3, and *p* 4, together with *m* 3, are more or less incomplete, and concealed in their closed alveoli.

Fig. 25.



DECIDUOUS AND PERMANENT TEETH OF THE HOG.

The premolars must displace deciduous molars in order to rise into place: the molars have no such relations. It will be observed that the last deciduous molar, *d* 4, has the same relative superiority of size to *d* 3 and *d* 2 which *m* 3 bears to *m* 2 and *m* 1; and the crowns of *p* 3 and *p* 4 are of a more simple form than those of the milk-teeth which they are destined to succeed.

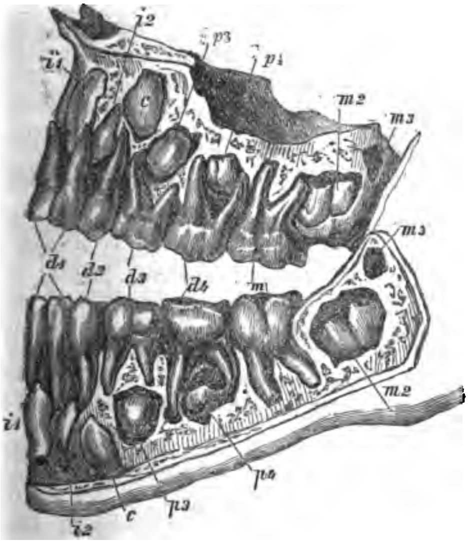
The germ of the permanent canine has not yet appeared below the deciduous one, *c*; those of the permanent incisors, *i* 1, *i* 2, *i* 3, are seen ready to push out the deciduous incisors *d* 1, *d* 2, *d* 3. When the whole of the second set of teeth is in place, its nature is indicated by the formula:—$i\frac{3-3}{3-3}, c\frac{1-1}{1-1}, p\frac{4-4}{4-4}, m\frac{3-3}{3-3} = 44$: which signifies that there are, on each side of both upper and lower jaws, three incisors, one canine, four premolars, and three molars, making in all forty-four teeth; each distinguished by the symbol marked in the cut.

When the premolars and the molars are below their typical number, the absent teeth are missing from the fore part of the premolar series, and from the back part of the molar series. The most constant teeth are the fourth premolar and the first true molar; and, these being known by their order and mode of development, the homologies of the remaining molars and premolars are determined by counting the molars from before backwards, *e.g.*, "one," "two," "three," and the premolars from behind forwards, "four," "three," "two," "one."

Examples of the typical dentition are exceptions in the actual creation; but it was the rule in the forms of mammalia first introduced into this planet; and that, too, whether the teeth were modified for animal or vegetable food.

With regard to the human dentition, the discovery by the great poet Goethe of the limits of the premaxillary bone in man, leads to the determination of the incisors, which are reduced to two on each side of both jaws; the contiguous tooth shows by its shape, as well as position, that it is the canine, and the characters of size and shape have also served to divide the remaining five teeth in each lateral series into two bicuspids and three molars. In this instance the secondary characters conform with the essential ones. But since we have seen of how little value shape or size are, in the order carnivora, in the determination of the exact homologies of the teeth, it is satisfactory to know that the more constant and important character of development gives the requisite certitude as to the nature of the so-called bicuspids in the human subject. In Fig. 26, the condition of the teeth is shown in the jaws of a child of about six years of age. The two incisors on each side, *d*, *i*, are followed by a canine, *c*, and this by three molar teeth like those of the adult; in fact, the last of the three, *m*, is the first of the permanent molars; it has pushed through the gum, like the two molars which are in advance of it, without displacing any previous tooth, and the substance of the jaw contains no germ of any tooth destined to displace it; it is, therefore, by this character of its development, a true molar, and the germs of the permanent teeth, which are exposed in the substance of the jaw, between the diverging fangs of the molars, *d* 3 and *d* 4, prove those molars to be temporary, destined to be replaced, and prove also that the teeth about to displace them are premolars. According, therefore, to the rule previously laid down, we count the permanent molar in place as the first of its series, *m* 1, and the adjoining premolar as the last of its series, and consequently the fourth of the typical dentition, or *p* 4.

Fig. 26.



DECIDUOUS AND PERMANENT TEETH, HUMAN, ÆT. 7.

We are thus enabled, with the same scientific certainty as that whereby we recognise in the middle toe of the foot the homologue of that great digit which forms the whole foot and is incased by the hoof of the horse, to point to *p* 4, or the second bicuspid in the upper jaw, and to *m* 1, or the first molar in the lower jaw, of man, as the homologues of the great carnassial, or flesh-cutting, teeth of the lion (Fig. 17). We also conclude that the teeth which are wanting in man to complete the typical molar series are the first and second premolars, the homologues of those marked *p* 1, and *p* 2, in the hog. The characteristic shortening of the maxillary bones required this diminution of the number of their teeth, as well as their size, and of the canines more especially; and the still greater curtailment of the premaxillary bone is attended with a diminished number, and an altered position of the incisors.

The homologous teeth being thus determinable, they may be severally signified by a symbol as well as by a name. The incisors, *e. g.*, are here represented by their initial letter, *i*, and individually by an added number, *i* 1, *i* 2, and *i* 3; the canines by the letter, *c*; the premolars by the letter, *p*; and the molars by the letter, *m*; these also being differentiated by added numerals. Thus the number of these teeth, on each side of both jaws, in any given species—man, *e. g.*—may be expressed by the following brief formula :—$i\,\frac{2-2}{2-2},\ c\,\frac{1-1}{1-1},\ p\,\frac{2-2}{2-2},\ m\,\frac{3-3}{3-3}=32$; and the homologies of the typical formula may be signified by *i* 1, *i* 2; *c*; *p* 3, *p* 4; *m* 1, *m* 2, *m* 3; the suppressed teeth being *i* 3, *p* 1, and *p* 2.

These symbols, it is hoped, are so plain and simple as to have formed no obstacle to the full and easy comprehension of the facts explained by means of them. If these facts, in the manifold diversities of mammalian dentition, were to be described in the ordinary way, by means of verbal phrases or definitions of the teeth—*e.g.*, "the second deciduous molar, representing the fourth in the typical dentition," instead of *d* 4, and so on—the description would occupy much space, and would levy such a tax upon the attention and memory as must tend to enfeeble the judgment, and impair the power of seizing and appreciating the results of the comparisons.

Each year's experience strengthens my conviction that the rapid and successful progress of the knowledge of animal structures, and of the generalizations deducible therefrom, will be mainly influenced by the determination of the nature or homology of the parts, and by the concomitant power of condensing the propositions relating to them, and of attaching to them signs or symbols equivalent to their single substantive names. In my work on the "Archetype of the Skeleton," I have denoted most of the bones by simple numerals, which, if generally adopted, might take the place of names; and all the propositions respecting the centrum of the occipital vertebra might be predicated of the figure "1" as intelligibly as of "basioccipital."

The symbols of the teeth are fewer, are easily understood and remembered, render unnecessary the endless repetition of the verbal definitions of the parts, harmonize conflicting synonyms, serve as a universal language, and express the author's meaning in the fewest and clearest terms. The entomologist has long found the advantage of such signs as ♂ and ♀, signifying male and female, and the like; and it is time that the anatomist should avail himself of this powerful instrument of thought, instruction, and discovery, from which the chemist, the astronomer, and the mathematician have obtained such important results.

RICHARD OWEN.

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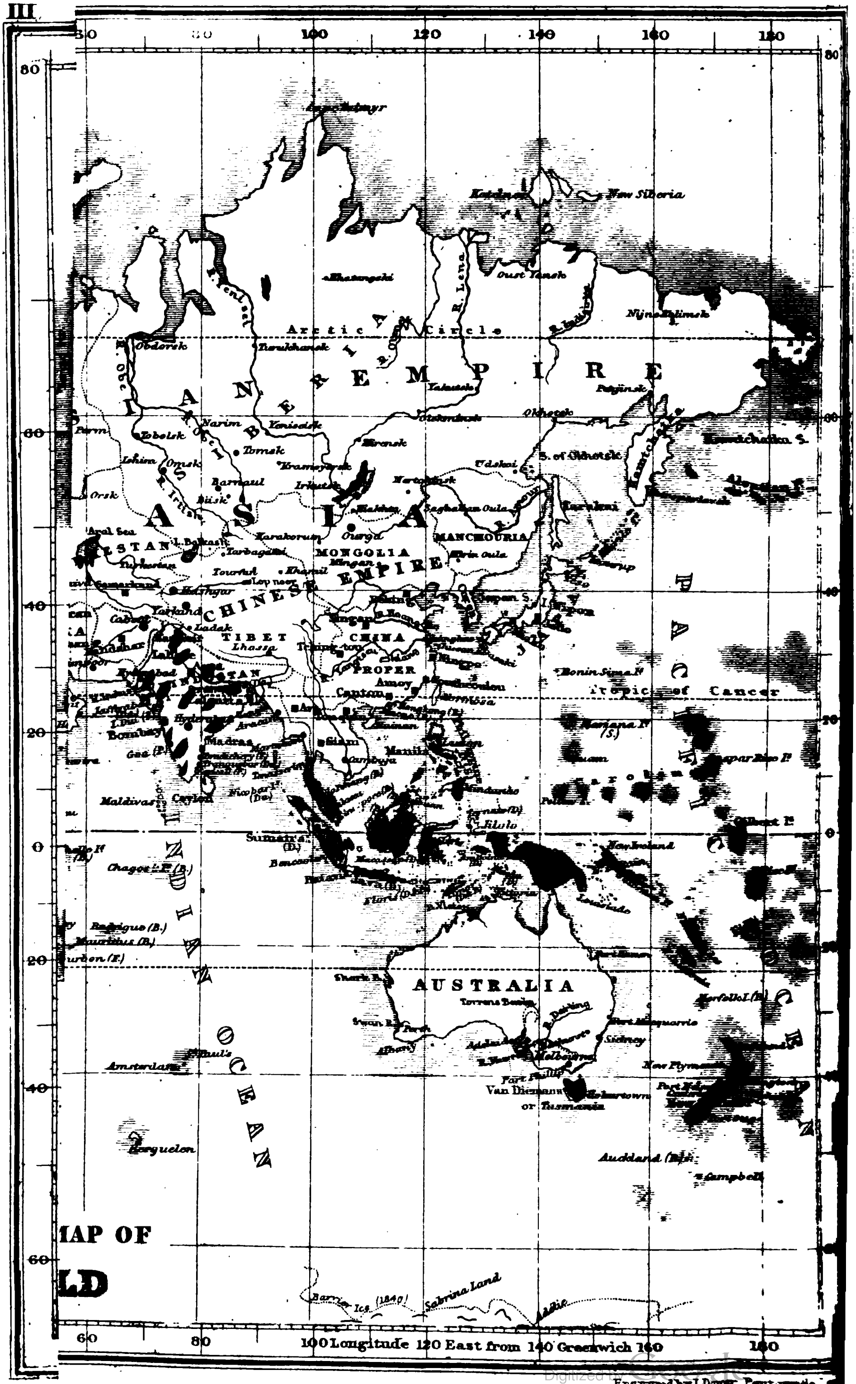
III



Engraved by I. Dower Pentonville

FR. BLUMENBACH.
Dr. LATHAM.
PRITCHARD

VARIETIES OF THE HUMAN SPECIES.

◆

General Introduction.—*Ethnology* is compounded of two Greek words, the latter of which scarcely requires explanation, because it already forms part of a numerous class of compounds with which the learned reader is well acquainted. The general reader, too, is perhaps equally familiar with them. We have them in such words as Geo-*logy*, Astro-*logy*, Physio-*logy*, and a long list besides. The Greek form of these would be Geo-*logia*, Astro-*logia*, &c. The basis of the term is the substantive *logos*, meaning a *word*. In its modified form, however, and in its application as the element of a compound word, it means the *principles*, or *science*, of the department (whatever it may be) that is denoted by the root which precedes it. In the word before us it means the *principles* of that department of human knowledge which is denoted by the form *Ethno*.

This is a word which we also have amongst us, though modified both in sound and sense. It is the root of the word *heathen*. The original meaning of *Ethnos* is *nation;* so that the word *heathen* takes its meaning as a term for *Pagan*, upon the same principle that the word *Gentile*, amongst the Jews, served to express, in the first place, a difference of *nationality;* in the second, a difference of creed.

In the word *Ethnology*, however, the first element appears in a form more closely approaching the original; and also, in a sense less remote from its proper signification, *Ethnology* means the science, not exactly of the different *nations of the world*, but of the different *varieties of the human species*.

Ethno-*graphy* is a similar derivation, the second element being the same as in Geo-*graphy*.

It would be convenient if these two compounds had their separate significations more strictly defined than they have them. Geo-*graphy* means one thing—Geo-*logy* another; and the two are never confounded. With Ethno-*logy* and Ethno-*graphy* this is not the case. Sometimes, indeed, a writer denotes by the latter term the strictly descriptive part of his subject, by the latter the *philosophy* (so to say) of it. But this distinction cannot always be observed; so that, taking language as we find it, we are not far wrong if we consider the two words as synonyms; synonyms which, in the progress of the science, are likely to be converted into distinctive terms, but which are, at present, used so loosely as to be nearly interchangeable. Of the two, Ethnology is the commoner.

No one who has seen a negro—no one, even, who has fallen in with a gang of gipsies—need doubt about the meaning of the term *Varieties of the Human Species*. If any consideration be excited in his mind at all, it must be that of the fact of man differing from man to an extent sufficient to develop a special department of scientific inquiry. Why this difference between the gipsy and ourself—the native Englishman? Why the still greater difference between ourself and the negro? In these three names we have three varieties, if we go no further. But we can go further; counting the changes in form and colour, not by threes, but by thirties—not by units, but by tens and hundreds. The Indian may be as black as the negro, but he has no such crisp and curly hair, no such thickened lips, (often) no such height of stature. He is liker, perchance, to the gipsy; at any rate he is the instance of another variety. Then there is the Chinese, different from both, and the Eskimo, and the Laplander, different from the Chinese, though, nevertheless, in his breadth of face, and scantiness of beard, not altogether unlike him. The American Indian gives us a fresh type, the Australian another, and so on throughout the whole inhabited world; change, difference, likeness; shapes the same, but colour different; colour like, but shapes varied; colour and shape agreeing, but stature differing. The investigation of these matters is Ethnology—*ethnos* (as aforesaid) meaning not so much a nation as a *variety*.

The differences that determine these varieties are of two kinds—physical or mental. The former were suggested when we spoke of hair, colour, and stature; the latter require a different kind of study—a different train of investigation. We *see* how a black differs from a white, and we perceive it even when we get beyond the palpable and unmistakable difference of colour. The texture of the hair differs as well as its hue,—a matter of which simple inspection informs us. But simple inspection will not tell us that the negro is a man of different ideas, habits, religious belief, and social organization; that his history has been unbrightened by great names in literature, art, or science; that his language is not only different from our own, but if allied to it, allied most remotely and indirectly. To know these things, we must have a certain amount of acquired information, based upon geography, based upon history, based upon philology, or the knowledge of language and languages. *Some* book-learning, in short, is necessary; in other words, the ethnologist has to read as well as to observe. At the same time, the best observer will make the soundest and safest teacher. This is because, though there is much in common between Ethnology and *civil* history, there is more in common between Ethnology and *natural* history. The method by which the geologist argues back from effect to cause, and so from the existing state of things reconstructs a former world, is eminently the method of the ethnologist. "Physical Archæology," writes Dr. Prichard, "includes both Geology and Ethnology. The former is the archæology of the globe, the latter that of its human inhabitants.

Both derive a part of their materials from different divisions of natural history. But Ethnology, as I have remarked, obtains resources for the history of nations and of mankind from many other quarters. It derives information from the works of ancient historians, and still more from the study of languages and their affiliations. The history of languages, indeed, greatly extended as it has been in late times, has furnished unexpected resources for the improvement of Ethnology."

Language (say the language of the negro) is a mental manifestation, and so is the civilization represented by his history, and each must be attended to as much as points of physical organization. The careful ethnologist neglects neither series of phenomena; so that philology and history go side by side with each other, and also along with the differences of corporeal structure. What manner of language does he speak? Who else speaks languages of the same class? Are these languages closely or remotely connected? What is the character of his civilization? Under what conditions has it been developed? Favourable or unfavourable? If unfavourable, has there been any natural inaptitude for certain forms of progress,—any inherent incapacity for development? What have been the physical conditions of the area to which such a tribe belongs?—what the animal and vegetable products?—what the opportunities of intercourse with other populations?

These, and their like, are the questions that arise even at the very onset of our ethnological career. They will not be enlarged upon at present—still less will they be answered. The only object with which, at the present stage of our inquiries, they are brought forward, is that of illustrating the scope and character of a department of knowledge which is one amongst the latest to have taken its due place and form in the circle of science; a new study, with a name of no great antiquity. More has to be said about it, both in respect to its methods of investigation and its relation to the other branches of knowledge; but this will be better done when a certain amount of details has been gone through. The best explanation of the character of a science is to be found in the working of it.

In dealing with the different varieties of the human species, according to the different classes under which they are arranged, it is better to begin with the old world, rather than the new, and with Asia rather than Africa or Europe. Of the Asiatic population the central and south-eastern should be taken first. There is a reason for this in the structure of their bodies; there is a reason also in the structure of their languages.

Bodily Structure.—The consideration of the head and face is sufficient; but of these we must remember that we take the bony parts as well as the soft. We must do more than this; we must give great importance to the form of the skull. It is upon this that some of our chief classifications have been based; for the skull is the receptacle of the brain, and the brain is the organ wherein the human species most differs from others. Now, one of the most extreme forms of skull is referable to these same central and south-eastern parts of Asia. It is the skull of the Mongolian of the northern and north-western frontier of China. Let us make a few preliminary observations; they will save some details of description. The distance between the two parietal bones of the cranium is the *parietal* diameter; that between the forehead and the occiput the *occipito-frontal*. Or—

Changing our expression for one less technical, we may say that every head has a side-to-side diameter, when measured from the parts above each ear; and a fore-and-aft diameter when measured from the forehead to the back of the head.

The former of these same diameters is the parietal (or inter-parietal), the latter the occipito-frontal. The former gives breadth, the latter length, to the head.

The fore-and-aft diameter is the longest—in nine cases out of ten, in nine hundred and ninety-nine out of a thousand; in a greater proportion still. Indeed, a head as broad as it is long is exceptional even amongst the broad-headed populations. But the difference between the diameters is very varied. When it is *more* than *two* inches, the skull is long-headed; when *less* than *one*, short-headed. This is a rough way of stating an important difference.

Then the molar (cheek) bones may be prominent; the zygoma, too, (the bone that can be felt through the skin to form a ridge from the cheek-bone to the ear) may make a wide curve outwards. This gives breadth to the *face*. Or the forehead may retire, which gives what is called a low facial angle. Or the upper jaw may slant forwards; in which case the insertion of the teeth will be *not perpendicular*, but *oblique*. This is being *prognathic*, from the word *pro*, forward, and *gnathos*, jaw. The opposite to this is *orthognathic*, from *orthos*, upright. A jaw may be so *prognathic* as to be almost a *muzzle*.

To return to the central and south-eastern parts of Asia, and to the *Mongolian* who occupies them. He is eminently—pre-eminently—short-headed, broad-skulled, and flat-faced; so much so, that the *Mongolian* conformation of the head and face is a recognised term of Ethnology. Many populations are characterized by it; or if not, by approaches to it more or less distant. The parts, then, in question supply us with a type of one sort.

Structure of Language.—The language of the Mongolian is not of the same extreme character as his bodily structure. It is neither remarkable for its development nor its want of development. But the Chinese, the language in immediate contact with it, *is* remarkable. It is one of a class, wherein there are no cases to the nouns, no tenses to the verbs, no declension, no conjugation, no inflection—no inflection, at least, after the fashion of the languages of Europe. Besides this, the separate words consist, for the most part, of single syllables. Hence it has been called *monosyllabic*—a term applied to the whole class. Now as this is the simplest form of speech, the parts in which it occurs are good parts to begin with. They supply us with a type in the way of language.

GROUP I.—*Physiognomy:* Mongol.—*Language:* Monosyllabic.—*Area:* Ladakh, Bultistan (or Little Tibet), Tibet, Nepal, Sikkim, Butan, Northern India, Arakhan, the Burmese Empire, Siam, Cambojia, Cochin-China, Tonkin, China, the Islands of Andaman, Nicobar, Carnicobar, Hainan, and the Mergui Archipelago.—*Divisions:* Tibetan (or Bhot), Siamese (or Thay), Burmese, Peguan (or Mon), Kambojian, Anamitic (or Cochin-Chinese), Chinese—various tribes, imperfectly distributed, and described as Sub-himalayans, Nagas, and Sifan—Mincopie (or Andaman Islanders), and Nicobarians.

The most constant characters of this vast and important group lie in the structure of their numerous languages, and in the conformation of the bony parts of the head and face. In complexion there are wide differences. The colour, however, of the hair is uniformly dark. Neither is there any broad separation between the taller and the shorter tribes in respect to stature. They are more under-sized than over-sized. The chief *physical* differences, as aforesaid, lie in the various tints of the skin. Mark the word *physical*, because when we come to the consideration of their civilization, industry, and intellectual development, we shall find that certain *moral* and *social* differences require notice, and that these are by no means inconsiderable.

The lightest-coloured tribes of this class are the natives of Cochin-China and Tonkin, who speak the Anamitic language, and who are not very widely separated from the true Chinese. These latter are tawny, or parchment-coloured; tawny or parchment-coloured so as to leave no doubt as to the character of their hue. It is yellow—yellow rather than either brown or black, yellow rather than copper-coloured, though this tinge is by no means unknown. In respect to the Anamese, it has been remarked that they wear more clothing, and expose the body less than any of the populations around them. Be it so. Yet I doubt whether this gives us the true reason for their comparative fairness. They lie between a mountain range and the sea; occupants of a district wherein no vast rivers form alluvial tracts, and where the wooded slope of the mountain side replaces the swamps of Cambojia, Pegu, and the other countries in the same latitude. Now the former are the conditions that most favour lightness of complexion; just as the latter determine a tendency to the colour of the negro.

The average height of the Cochin-Chinese of the seaports is low: a fact to which both Craufurd and Finlayson bear witness. The former considers them to be lower in stature than any people of Central (*sic*) Asia; the latter compares them with the Chinese, but makes their average height something less. The upper extremities are long, the lower short and stout, at least with the males; who, if squat and somewhat ill-favoured in aspect, are hardy and active. The women, on the other hand, are disproportionately fairer and handsomer than the men, for their extremities are well formed, and the carriage, even amongst the lower orders, is graceful. The form of the skull is more globular than square, the eyelids less turned than those of the Chinese. The mouth is large, the lips more prominent than thick, the moustache more abundant than the beard. Craufurd compares their features to those of the Malays, except that they bear none of the Malay expression of ferocity, but, on the contrary, exhibit good humour and cheerfulness. And this seems to be their character. The lower orders are eminently lively, talking and laughing as if their government were as satisfactory and agreeable as it is despotic and oppressive. The higher classes, however, are solemn and decorous, after the manner of the Chinese. Their dress is that of the Chinese before they adopted that of their Mongol conquerors. It varies but little with the sex, consisting, with both men and women, of loose trousers, and a loose frock reaching half-way down the thigh. The sleeves are loose; and when the wearer has no need to labour, hang a foot or foot and half over the fingers. The ankles and neck only go bare. The hair is worn long, and put up in a knot at the back of the head: this, too, being the old and original Chinese practice. A straw hat, which is sometimes in the form of an inverted basin and sometimes like a sugar-loaf—which is of great breadth in the rim, and which is constantly worn out-of-doors—is a good fence against the sun. As to the materials of the clothing, they are generally silk or cotton—oftener silk than in any other country. Metallic ornaments are far rarer, as Tonkin is the only one of the three parts of the Anamitic Empire where mineral wealth is abundant—or, at least, the only one where it has been worked to any extent. White is the colour of the national flag—white is the colour for mourning: but the royal colour is yellow or orange.

The use of the cigar, and of the usual masticatories, is universal, except that the Cochin-Chinese does not add catechu to his mixture of betel, quicklime, and areca.

Neither do they go far in the way of ornamental disfigurement. There is no pride in an unduly small foot, as in China; and no filing of the teeth, or enlargement of the ears, as among so many of the Malay tribes.

The government is despotic, and the punishments cruel; the religion is Buddhist, but latitudinarian, as in China. There is little vitality in any of their venerational feelings, save and except those which are so embodied in the respect shown towards the *manes* of their ancestors.

Marriage takes place later than in most of the other parts of Asia; for if the rich sometimes marry at fifteen, the poor often remain single till thirty. The age of the female is from seventeen to twenty, at least in the lower orders. In no country—our own not excepted—is the date of the marriage more regulated by the ways and means of the parties contracting. A Cochin-Chinese marries as soon as he can; but his wife must be purchased. Marriages are indissoluble; but as polygamy is habitual, the first wife has a pre-eminence over the others. Abortion is commoner than infanticide, and a violation of the laws of chastity amongst unmarried women commoner than either. Adultery, however, is an offence of the gravest nature, of which the legal punishment, though often commuted for milder penalties, is death. Without being jealously confined, as in the Turk and Persian parts of Asia, the Anamitic women are coarsely and often brutally treated. The infliction of corporeal punishment on an offending wife passes without comment, and as a matter of course.

Less industrious than the Chinese, the Cochin-Chinese are also less ingenious. Their arts, however, are the same in kind, though on a lower level of excellence. Begging is rare in Cochin-China; so is emigration; so is *not* highway robbery. A French gentleman informed Mr. Craufurd, as a proof of the vigorous administration of Thas Kun, governor of Kambojia, that he reduced the number of capital trials from 300 *per annum*, to 3 or 4.

The contrast to the Anamese must be sought in the Mincopie of the Andaman islands. These are called *Blacks*—without qualification—by the few observers who have described them. Nay more, they have been ignored as members of the class under notice, and been placed amongst the Papuas of New Guinea, and the so-called Arufuras of the Indian Archipelago. Yet their language shows them to belong to the same division with the Burmese of the opposite continent.

These Andaman islanders are mentioned as early as the twelfth century, *i. e.*, by the two Mahometan travellers of Renaudot. These write, that beyond the Nicobar Islands "lies the sea of Andaman. The people on this coast eat human flesh quite raw; their complexion is black, their hair frizzled, their countenance and eyes frightful; their feet are very large, and almost a cubit in length, and they go quite naked. They have no embarkations; if they had, they would devour all the passengers they could lay hands on." Marco Polo writes equally unfavourably—"Angaman is a very large island, not governed by a king. The inhabitants are idolators, and are a most brutish and savage race, having heads, eyes, and teeth resembling those of the canine species. Their dispositions are cruel; and every person, not being of their own nation, whom they can lay hands on, they kill and eat."

A paper, by Lieutenant Colebrooke, is the chief source of our knowledge concerning the Mincopie, the author being indebted to his predecessors, Major Kyd and Captain Blair, for some of his facts. He describes them as plunged in the grossest ignorance and barbarity; barely acquits them of the charge of cannibalism; and unhesitatingly affirms that the murder of the crews of such vessels as may be wrecked upon their coast is their invariable habit. The late Sir Charles Malcolm, however, who had had one of the natives aboard-ship with him, took considerable pains to dilute the charges that thus lay against this ill-famed population, and spoke in strong terms as to the gentleness and docility of the individual with whom he thus came in contact.

The Mincopie are skillful in shooting fish with their arrows. They take, however, but little pains to cultivate the soil—feeding on what they find or kill; they are fond of singing and dancing; ignorant of the art of working in metal; but not unskilful in the management of their canoes. These are hollowed out of the trunks of trees by means of fire, or instruments of stone. Sometimes they use rafts of bamboos. Their bows are remarkably long. Hand-nets, wicker-baskets, and a few specimens of pottery-ware have been seen amongst them.

The Mincopie of the Andaman Islands, and the Cochin-Chinese, have been dealt with more fully than will be the case with any other members of this group, because they are fair specimens of two extremes—of the dark-skinned as opposed to the fair, and of the rude as opposed to the refined.

Between the two, there is every shade of intermediate colour. As a general rule, however, the lower the sea level of a locality, the more alluvial its soil, and the moister the character of its heat, the blacker the tint of the inhabitants.

The Burmese grow darker as the Valley of the Irawadi becomes broader and flatter. The men of Pegu, who hold the delta, are darker than the Burmese.

The hair of these, as of all other families, must be viewed in respect to two of its characters—its colour and its texture.* The colour with those before us is the more uniform of the two. It is what is ordinarily called *black*. We know what this means; but we should also know that, in strict reality, there is no such thing as absolutely black hair. A negro's hair is black only when the light falls straight upon it. When seen in a cross light, it has a red tinge—red, red-dish, or brown; more red, however, than aught else. As the black decreases, the colour becomes chestnut, auburn, bright red, sandy, flaxen, yellow, and white (so-called). However, there is no such thing as truly black hair. The word means merely—*very dark*. It will be used; but it must be understood that this is its meaning. Now I have not found any notice of any members of the family having hair sufficiently red to be called other than *black*; yet such a notice would not surprise me. I expect it. For tribes closely allied to them I find the epithets *reddish* applied more than once. This merely means that the red element has become pronounced enough in its character to strike the ordinary observer. So the hair with the family under consideration is *black*, according to common parlance. In texture it is straight, but not of the straightest and harshest kind. There is an occasional approach to a wave, or curl. In this case writers call it *crisp*, or *wavy—crisp*, if it be hard; *wavy*, if fine, soft, and silky.

The crisper the hair, the more abundant the beard. As a general rule, however, we are to expect smooth, and, comparatively speaking, beardless faces.

The eye is often set obliquely; that is, the outer angle is drawn upwards. Sometimes, in addition to this, the upper eyelid hangs heavy and tumid over the eyeball; and sometimes the skin forms a crescentic fold between the inner angle of the eye and nose; as may be seen in individuals out of China, and which is not uncommon in England.

With the Chinese this is the most remarkable. In some, the peculiarity entirely disappears. But the superficial character of these distinctions has been already suggested; the bony parts being pretty constant in character throughout the group.

If the physical differences, when properly valued, lie within narrow limits in the class before us, it is not the case with the moral ones. For with these we find strong contrasts without always finding intermediate and transitional grades between them. The forms of barbarism are numerous. There are, as we have seen, the outlying Mincopie, almost the only islanders of the class who are savage after the fashion of men cut off from the world by the sea. There are the occupants of the hill ranges between India and the Burmese Empire, who are savages after the fashion of mountaineers, secluded in their respective valleys, sectional in their feelings, mutually hostile to each other, ignorant of the world beyond; and, as such, untouched by the influences that have promoted the civilization of Ava, Siam, and China.

The civilization of the monosyllabic populations is more uniform in its character than their barbarism. Nor is this a matter of surprise. It has chiefly originated in one quarter—India. From India it has been diffused. The history of the alphabets of Ava, Siam, Pegu, &c., tell us this. So does the history of the Buddhist religion. With a few exceptions—exceptions which will be specially noticed—all the populations of the class before us, that have arisen to anything beyond their primitive paganism, are Buddhists in creed. The Burmese are Buddhist; the Siamese, Buddhist; the Mon of Pegu, Buddhist; the Cambojians, Buddhist; the Tibetans, Buddhist; the Chinese, Buddhist; all of which are more or less civilized, all of which use an alphabet; all of which either form of themselves, or belong to, large consolidated empires. It is not necessary to dilate on these. They attain their greatest development in China. Bultistan is Mahometan; Nepal, Brahminic.

The ruder tribes, on the other hand, claim more of our attention, since it is these that give us the idea of the primitive condition of the family anterior to the introduction of foreign influences. Their *habitats* have been already suggested. They are rude because they are isolated, and they are isolated because they are either mountaineers or islanders.

We have seen that the islanders are few—viz., the Mincopie and the Nicobarians, to which may be added the inhabitants of the Mergui Archipelago, off the coast of Tenasserim. The islanders are few, for the family is eminently the family of a *continent*. It has a small sea-board; but it uses what it has. The Chinese are one of the nautical populations of the world.

The mountaineers are referable to four groups, and these are geographical rather than ethnological; it may also be added, that in the present state of our knowledge they are convenient and provisional rather than absolutely accurate.

1. The first is called the *Sub-Himalayan*. It extends along the south side of the Himalayas, from Kumaon to Assam.

2. The second belongs to the mountains of the south-western provinces of China, touching the Burmese frontier, and extending into Tibet. This is designated by a Chinese name *Sifan*, meaning *western barbarians*.

3. The third gives us the occupants of the mountain-range that incloses the valley of Assam.

4. The fourth lies southwards, and includes the tribes that belong to the hills and forests that separate the lower parts of the rivers Irawadi and Menam, Menam and Mek-hong, the Mek-hong and Cochin-China. In other words, they are the tribes that lie between Burmah and Siam, Siam and Cambojia, Cambojia and Cochin-China, respectively.

The name of these is *legion*, and *legion* is the name of their mutually unintelligible forms of speech. Not that they are radically different from either each other, or from the languages of the surrounding countries; on the contrary, they can generally be referred to some of the greater stocks around them—mostly to the Tibetan and the Burmese. Again, these rude mountain tribes serve as measures of the completeness or incompleteness of the conquest and consolidation on the part of the more potent kingdoms, Ava (or the Burmese Empire), Siam, and China; inasmuch as they generally represent the aborigines of districts which have preserved their independence.

And now to a sketch of some of the details.

1. *The Sub-Himalayans.*—A large proportion of that part of India, which lies to the north of the Ganges and to the south of the Himalayas, is monosyllabic in speech. It is Tibetan or Burmese, rather than Indian Proper; and the tribes are small and varied; yet only on the southern slope. The moment we pass the ridge, and get amongst the Bhot of Tibet, the language becomes wonderfully uniform, and that over a vast range of country. So that the rule is thus:—

a. A large area, with a single form of speech, on the side of Tibet.

b. A small area, with a multiplicity of languages, on the side of India.

As the Indians have encroached from the south, the monosyllabic tongues originally extended farther into Hindostan than they do now; perhaps, as far south as the Ganges. They also, probably, extended farther westwards. How far no man can say. Be this as it may, we first meet with monosyllabic forms of speech on the Kumaon frontier of Nepal, spoken by the Chepang, Kusunda, and Hayu,—wild, weak, and scattered tribes that demand more than a passing notice.

The mountaineers of the western parts of Nepal are, themselves, short in stature; so that there is not much contrast between them and the Chepang in the matter of height. It is in colour and bulk where the difference chiefly lies. The Chepang are slightly made, with large bellies and thin legs; the skin being dark brown, approaching to black, or, as Mr. Hodgson calls it, nigrescent brown. The head has a fore-and-aft development, the other characteristics being definitely Mongolian—*i. e.* the face is flat, and the eye small, but the mouth projects.

In these *differentiæ*, in the way of physical appearance, I see a repetition of what I shall point out elsewhere. A population is naturally and normally somewhat undersized in point of height, Mongolian in physiognomy, and olive-coloured as to its skin. With deficient nutrition, deficient clothing, and deficient civilization, it becomes thin and *black*. The rudeness of the Chepang is as evident as their darkness. They live entirely upon the products of the forest and waste.

Nepal is consolidated into a kingdom, full of Hindu blood, and modified by Hindu influences. Yet the original inhabitants are the monosyllabic Magars, Gurungs, Sunwars, Newars, Murmis, Kiratas, and Limbus, leading to the Lepchas of Sikkim. Then the physical conditions change as we approach the alluvial soil, the damp heat, and the forest malaria of the water-system of the Lower Ganges, when the Koch, Mech (or Bodo), and Dhimal of Sikkim and Coosh Bahar, like the Chepang, take the colour of the Indian. The Garo mountaineers bring us to the very bank of the Burampooter.

This division runs far eastwards into the Kasia country and Jaintia Hills, falling into divisions and sub-divisions, dialects and sub-dialects. The farther it stretches eastwards the more Burmese it becomes in its affinities. In northern Burmah the mountain tribes are called Nagas.

2. *The Sifan.*—China I believe to have been conquered from the south-east, (say) from the valley of the Canton river. Hence the northern provinces have been added

to the empire within the historic period; the western parts still retain a sort of independence. Some of these tribes of the Sifan may be Chinese—others are more Tibetan than Chinese, as has been shown by the only competent authority on these obscure topics—Mr. Bryan Hodgson, of Nepal.

3. *The Assam Mountaineers.*—The mountains that surround Assam, beginning on the north and west, contain the Aka, the Dufla, the Abor, and Bor-abor; the Miri, the Miskimi, the Jili, and the Singpho, these last being on the north-east corner.

We then turn round and move along the southern frontier from east to west, through the country of the Muttuck, till we reach the Kasia, Cachar, and Jaintia populations in Silhet, and the parts about the Garos.

But the northern part of Burma, the parts about Manipur, though not exactly Naga, abound in dialects and sub-dialects. The last twelve of the following table show this:—

	A'bor,	A'ká,	Mishimí,	Burmese,	Karen,	Singpho,	Jilí,	Gáro,	Manipurí,	Songpú,	Kapwí,	Koreng,	Marám,	Champhung,	Luhuppa,	N. Tángkhul,	C. Tángkhul,	S. Tángkhul,	Khoibú,	Maring.
A'bor		47	20	17	12	15	15	5	11	3	10	3	8	8	8	5	6	10	8	10
A'ká	47		20	11	10	18	11	6	15	6	11	5	8	6	8	8	8	10	10	18
Mishimí	20	20		10	10	10	13	10	11	0	11	0	3	5	6	8	6	13	10	8
Burmese	17	11	10		23	23	26	12	16	8	20	6	11	11	11	10	13	13	16	16
Karen	12	10	10	23		17	21	8	15	10	15	8	12	4	12	8	12	12	10	15
Singpho	15	18	10	23	17		70	16	25	10	18	11	11	13	15	13	25	13	20	18
Jilí	15	11	13	26	21	70		22	16	10	21	13	11	11	18	20	20	13	20	20
Gáro	5	6	10	12	8	16	22		10	5	6	5	8	5	8	13	11	5	5	5
Manipurí	11	15	11	16	15	25	16	10		21	41	18	25	28	31	28	35	33	40	50
Songpú	3	6	0	8	10	10	10	5	21		35	50	53	20	23	15	15	13	8	15
Kapwí	10	11	11	20	15	18	21	6	41	35		30	33	20	35	30	40	45	38	40
Koreng	3	5	0	6	8	11	13	5	18	50	30		41	18	21	20	20	—	10	15
Marám	8	8	3	11	12	11	11	8	25	53	33	41		21	28	25	20	16	23	26
Champhung	8	6	5	11	4	13	11	5	28	20	20	18	21		40	20	20	16	15	25
Luhuppa	8	8	6	11	12	15	18	8	31	23	35	21	28	40		63	55	36	33	40
N. Tángkhul	5	8	8	10	8	13	20	13	28	15	30	20	25	20	63		85	30	31	31
C. Tángkhul	6	8	6	13	12	25	20	11	35	15	40	20	20	20	55	85		41	45	41
S. Tángkhul	10	10	13	13	12	13	13	5	33	13	45	11	16	16	36	30	41		43	43
Khoibú	8	10	10	16	10	20	20	5	40	8	38	10	23	15	33	31	45	13		78
Maring	10	18	8	16	15	18	20	5	50	15	40	15	26	25	40	31	40	43	78	

This table illustrates a valuable collection of vocabularies made by Mr. Brown. The table is often quoted as "Brown's Table." It shows the per-centage of words common to any two of the languages contained in it, and supplies a good measure of the difference and likeness between a multiplicity of dialects packed up within a small area. The affinities here are with the Burmese, and more remotely with the Tibetan and Siamese. Still more Burmese are the Khyen and Kariens, along with a series of populations known as Kuki, Lunctas, and Khumias; whereas the Khamti and Lau belong to the Siamese division.

I enlarge upon these matters, not because I believe that much good comes from long lists of names, but for the sake of showing two phenomena of far more value and importance. Firstly, I wish to show that out of a great number of mutually unintelligible tongues, none are wholly isolated; but, on the contrary, that they can generally be apportioned to one of the larger classes, such as the Tibetan, the Siamese, or the

Burmese. Secondly, I draw attention to what may be called the contrasted characters of different areas. In China, in Tibet, in Siam, a single tongue covers a vast space. Elsewhere, a single tongue is limited to a remarkably small area. It may be well to mark this juxtaposition of large and small groups, and to watch whether it is a phenomenon peculiar to the monosyllabic family, or whether it repeats itself elsewhere, and re-appears as an ordinary fact in other ethnological groups. It will be found to be in the latter predicament.

4. *The Lolo, Quanto, and Moy.*—These are the mountaineers of the parts between Siam, Cambojia, Cochin-China, and China. We know little of them. They probably bear the same relation to the Chinese, Cochin-Chinese, and Cambojians, that the last group did to the Burmese, Siamese, and Tibetan.

We are not acting over boldly if we attempt to draw a picture of that early state of the monosyllabic populations which preceded the consolidation of the great empires, China, Burma, Siam. The low state of its civilization must be that of the rudest of the mountain tribes. The areas, too, of the individual tribes must have been small; of which, however, one spreads at the expense of its neighbours. These it either modifies or obliterates—moving onwards in a given direction, or (at least) from a given starting-point.

It is the business of the ethnologist to ascertain, as far as possible, these starting-points, and to indicate the direction of the lines of conquest. If history helps, all is easy—not so if she be silent. He must, then, proceed inductively; and, to do this, he has recourse to the phenomena of language. This always teaches something, and I *think* that in the present instance its teaching is as follows:—

a. The more we follow the Chinese language northwards and westwards, the more we find it contrasted with the languages with which it comes towards contact; and the more we follow it in the direction of Tonkin and Cochin-China, the more similarity we find. This suggests a direction to the line of conquest and migration from south and east to north and west.

b. The shape of the ground covered by the Siamese class of languages is remarkable. Narrow in the direction of east and west, it is of enormous length from north to south. More than this, it follows, with a considerable degree of closeness, the valley of the river Menam. Did the stream of conquest and migration coincide with that of the river, and did the invaders of the lower districts descend from the country of its head waters? Probably. At any rate, the Khamti language spoken on the frontier of Assam is so like the Siamese of the capital, that in Brown's tables the per-centage of words common to the two is ninety-two. Yet there are nineteen degrees of latitude between them.

Similar reasoning suggests a northern origin, and consequently a southerly line of direction, to the Burmese. They grow more like the languages with which they come in geographical contact, just in proportion as they are examined in their northern dialects; the converse having been the case with the Chinese.

We have now seen, within a very moderate range of physical and philological differences, both samples of comparative civilization, and samples of the ruder forms of barbarism. But we must remember, that the physical and other conditions of the area over which the populations before us have been spread, are also different. Of islands and of insular conditions there was but little; but there was a considerable range of climate, both as measured by the degrees of latitude, and by the height above the sea level. There were boundless plains, and narrow mountain valleys. There was also a wide range both of vegetation and animal life. As domestic animals, there was the elephant in the intertropical jungles of Siam, and the yak on the snowy Alps of Tibet. There was rice, as a cereal, and millet, as a cereal. In China there were the tea-tree and the silk-worm. A remark or two on the phenomena of speech will now lead us to the next group.

The relations of time and place, in the languages of the previous group, have been expressed by separate words placed in juxtaposition, but not incorporated, with each other. But what if such words, originally distinct, unite? In such a case we have the beginning of a system of inflection. The structure of languages in this stage of development is said to be *agglutinate*. Here one word is incorporated with another; at the same time the fusion of the two is sufficiently incomplete for the original and independent character of the annexed word to show itself.

GROUP II.—TURANIANS.—*Physiognomy:* Mongol.—*Language:* Agglutinate.—*Area:* Mongolia, Mantshuria (the parts north of Pekin—the valley of the River Amur, Selinga, or Saghalin), Siberia, Independent Tartary, Chinese Tartary, Turkistan, Anatolia, Roumelia (or Turkey in Europe), parts of Bokhara, Persia, Armenia, Syria, the Crimea; Lapland, Finland, Esthonia, Livonia, the Russian governments of Archangel, Olonetz, Novogorod, St. Petersburg, Tver, Yaroslav, Vologda, Permia, Viatka, Kazan, Simbirsk, Saratov, Astrakhan, Caucasus, Nizhninovogorod, Penza, Tambov—Hungary—the Kurile Isles, Japan, Kamskatka.

Primary Divisions.—1. The Mongolian stock. 2. The Tungusian stock. 3. The Turk stock. 4. The Ugrian stock. 5. The Peninsular stock.

These five divisions constitute the great *Turanian* class, which some call *Scythian*. The proposed name is Persian. Much as the Greeks and Romans called all nations except themselves *barbarians*, the ancient Persian, designated by the name *Turan* all those parts of Central and Northern Asia from which so many wild and formidable enemies were in the habit of descending upon the south. The ancestors of the Turks, Mongols and Ugrians, were assuredly among them.

The Mongolians.—Bounded by Tibet, China, the Mantshu country, Siberia, Independent Tartary, and Chinese Tartary, lies, in the centre of Asia, the country of the Mongols, or Mongolians Proper, the Mongols, or Mongolians, in the limited and special sense of the word.

Kiatka, their frontier town, on the boundaries of Russia and China, lies more than 2400 feet above the sea-level—without being situated on a mountain. This, as Mr. St.. John remarks in his paper on the Mongols, is higher than "the towns of the Hartz, or the Swiss Alps; and there is a continual rise to Urga."* In fact, Mongolia is the most elevated part of the great Asiatic steppe—the watershed to two systems of rivers, the rivers that, like the Yenesy and the Lena, fall into the Arctic Sea, and the rivers that, like the Hoang-ho, the Menam, and the Mekhong, fall into the China Sea. Mongolia is the widest watershed in the world—extreme in climate, bare in surface. And the Mongolians are the most nomadic of populations. The horse, the sheep, and the small black buffalo of the steppes are their domestic animals; their home, the tent; their food, milk more than flesh, and flesh more than corn.

We are prepared for the physiognomy of the Mongolians—for his flat face and broad skull, and for the oblique eye; for exaggerations of the Chinese types. The current power of the term Mongolian, in its wider and more general sense, implies this. Add to this, that the nation lives almost on horseback, and has the legs short, the feet small, the calves undeveloped, and the knees bent out; with thick thighs, small waists, and long vigorous arms. The statement, that the breadth between the eyes is that of a man' hand, is an exaggeration; so is the statement that a ruler laid across the two cheekbones would pass over the depressed nose without touching it. The nasal bones are certainly but little elevated; but in the case of the eyes the distance is apparent rather than real. The inner margin of the orbits, the eye itself, are not inordinately separated from each other. It is the crescentic fold at the inner angle of the eye, covering as it does the lacrymal gland, that gives the breadth. The insertion of the teeth is oblique; the upper maxillary bone massive; the zygomas curved outwards. It is this outward curve of the zygomas that makes faces flat; and the size of the maxillary that gives them roundness and fulness in the middle parts. If the *lower* jaw also be massive, the face is round or square; but it is often pointed, and so the face gets compared to the lower half of a lozenge.

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* "Journal of the Ethnological Society," vol. i.

This physiognomy is uniform throughout Mongolia, and the habits of the Mongolian are uniform also.

The great conqueror, Zingiz-Khan, was a Mongolian. He is generally spoken of as a Tartar, but Mongolian is the better term. Zingiz-Khan was a Mongolian and not a Turk. Tamerlane was a Turk and not a Mongolian. China was conquered by the Mongols rather than by the Turks; India by the Turks rather than the Mongols. Yet India is the empire of the Great Mogul, and both conquests are called Tartar conquests. Under Zengiz-Khan and his immediate successor, all the parts between the China Sea and the frontier of Bavaria were overrun by Mongols.

At present, the Mongolians are quiet, peaceable Buddhists—no conquerors at all, but rather monkish-minded men, subject to China — a few to Russia. Such being the case, it is difficult to realize a notion as to what they were when Europe trembled at their name. The notices of the Venetian traveller, Marco Polo, who visited the court or camp of the grandson of Zengiz-Khan, best help us here.

In their nomadic habits they were much the same then as now. "The Tartars," so writes Marco Polo, meaning by Tartars the Mongolians, "never remain fixed, but as the winter approaches remove to the plains of a warmer region, in order to find sufficient pasture for their cattle; and in summer they frequent cold situations in the mountains, where there is water and verdure, and their cattle are free from the annoyance of horse-flies and other biting insects. During two or three months they progressively ascend higher ground, and seek fresh pasture; the grass not being adequate in any one place to feed the multitudes of which their herds and flocks consist. Their huts or tents are formed of rods covered with felt, and being exactly round, and nicely put together, they can gather them into one bundle, and make them up as packages, which they carry along with them in their migrations, upon a sort of car with four wheels. When they have occasion to set them up again, they always make the entrance front to the south. Besides these cars, they have a superior kind of vehicle, upon two wheels, covered likewise with felt, and so effectually as to protect those within it from wet, during a whole day of rain. These are drawn by oxen and camels, and serve to convey their wives and children, their utensils, and such provisions as they require. The women attend to their trading concerns, buy and sell, and provide everything necessary for their husbands and their families; the time of the men being entirely devoted to the employment of hunting and hawking, and matters that relate to military life. They have the best falcons in the world, and also the best dogs.

They subsist entirely upon flesh and milk, eating the produce of their sport, and a certain small animal, not unlike a rabbit, called by our people *Pharaoh's mice*, which, during the summer season, are found in great abundance in the plains. But they likewise eat flesh of every description, horses, camels, and even dogs, provided they are fat. They drink mares' milk, which they prepare in such a manner that it has the qualities and flavour of white wine." This is much similar to what takes place at present.

They were polygamists, and that of a peculiar kind. "The men are allowed the indulgence of taking as many wives as they choose. Their expense to the husband is not great, and on the other hand the benefit he derives from their trading, and from the occupations in which they are constantly engaged, is considerable; on which account it is, that when he receives a young woman in marriage, he pays a dower to her parent. The wife who is the first espoused has the privilege of superior attention, and is held to be the most legitimate, which extends also to the children borne by her. In consequence of this unlimited number of wives, the offspring is more numerous than amongst any other people. Upon the death of the father, the son may take to himself the wives he leaves behind, with the exception of his own mother. They cannot take their sisters to wife; but upon the death of their brothers they can marry their sisters-in-law. Every marriage is solemnized with great ceremony."

More valuable are the scanty notices of their original Pagan creed, now displaced by Buddhism. "They believe in a Deity whose nature is sublime and heavenly. To him they burn incense in censers, and offer up prayers for the enjoyment of intellectual and bodily health. They worship another likewise, named *Natigay*, whose image, covered with felt or other cloth, every individual preserves in his house. To this deity they associate a wife and children, placing the former on his left side, and the latter before him, in a posture of reverential salutation. Him they consider as the divinity who presides over their terrestrial concerns, protects their children, and guards their cattle and their grain. They show him great respect; and at their meals they never omit to take a fat morsel of the flesh, and with it to grease the mouth of the idol, and at the same time the mouths of its wife and children. They then throw out of the door some of the liquor in which the meat has been dressed, as an offering to the other spirits. This being done, they consider that their deity and his family have had their proper share, and proceed to eat and drink without further ceremony. The rich amongst these people dress in cloth of gold and silks, with skins of the sable, the ermine, and other animals. All their accoutrements are of an expensive kind."

Barbarous in their funeral ceremonies, they made it an "invariable custom that all the grand *kans*, and chiefs of the race of *Chingis-kan*, should be carried for interment to a certain lofty mountain, named *Altai;* and in whatever place they may happen to die, although it should be at the distance of a hundred days' journey, they are, nevertheless, conveyed thither. It is likewise the custom, during the progress of removing the bodies of these princes, for those who form the escort to sacrifice such persons as they chance to meet on the road, saying to them, 'Depart for the next world, and there attend upon your deceased master!' being impressed with the belief that all whom they thus slay do actually become his servants in the next life. They do the same also with respect to horses, killing the best of the stud, in order that he may have the use of them. When the corpse of *Mongù* was transported to this mountain, the horsemen who accompanied it, having this blind and horrible persuasion, slew upwards of ten thousand persons who fell in their way."

The organization of a people of conquerors always commands attention; and Marco

Polo's narrative supplies information on this point:—"When one of the great Tartar chiefs proceeds on an expedition, he puts himself at the head of an army of a hundred thousand horse, and organizes them in the following manner:—He appoints an officer to the command of every ten men, and others to command a hundred, a thousand, and ten thousand men respectively. Thus ten of the officers commanding ten men take their orders from him who commands a hundred; of these, each ten from him who commands a thousand; and each ten of these latter from him who commands ten thousand. By this arrangement, each officer has only to attend to the management of ten men, or ten bodies of men; and when the commander of these hundred thousand men has occasion to make a detachment for any particular service, he issues his orders to the commanders of ten thousand to furnish him with a thousand men each; and these, in the like manner, to the commanders of a thousand, who give their orders to those commanding a hundred, until the order reaches those commanding ten, by whom the number required is immediately supplied to their superior officers. A hundred men are in this manner delivered to every officer commanding a thousand, and a thousand men to every officer commanding ten thousand. The drafting takes place without delay, and all are implicitly obedient to their respective superiors. Every company of a hundred men is denominated a *tuc*, and ten of these constitute a *toman*.

"When the army proceeds on service, a body of men is sent two days' march in advance, and parties are stationed upon each flank and in the rear, in order to prevent its being attacked by surprise. When the service is distant, they carry but little with them, and that, chiefly, what is requisite for their encampment, and utensils for cooking. They subsist for the most part upon milk, as has been said. Each man has, on an average, eighteen horses and mares, and when that which they ride is fatigued, they change it for another. They are provided with small tents made of felt, under which they shelter themselves against rain. Should circumstances render it necessary, in the execution of a duty that requires dispatch, they can march for ten days together without dressing victuals: during which time they subsist upon the blood drawn from their horses, each man opening a vein and drinking from his own cattle. They make provision also of milk, thickened and dried to the state of a hard paste (or curd), which is called *kumis*."

The Mongolians are related, on the one hand, to the *Turk*, on the other to the *Tungusian* stocks—to the Turks on the west, to the Tungusians on the north and east. The first in order of notice will be

The Tungusians.—The Russian government of Irkutsk is the great centre of this stock, but they also extend beyond it. There are Tungusians as far west as the river Yenisey, and Tungusians as far east as the sea of Okotsk. There are Tungusians at the neck of the peninsula of Kamskatka, and Tungusians all along the northern frontier of China. Indeed, the Chinese and Tungusian boundaries touch each other; the Chinese being the population that encroaches. We find this if we read about the parts north of the Great Wall, or if we study the geography of the great river Amur, or Selinga. Different maps give us different names. The older are Tungusian, the newer Chinese. In several, the nomenclature is bilingual. There is the original Tungusian name for a place, and there is the Chinese synonym or translation of it. So that, in respect to industry, commercial enterprize, and the other means by which, during a time of peace, one nation encroaches on another, the Chinese may reasonably be supposed to have the advantage. He helps to civilize the Tungusian. This is what the Greek did with the Roman. The Roman, nevertheless, was the lord and master, the conqueror in the time of war. And so it is here. The last of the so-called Tartar dynasties that conquered China, the dynasty that, at the present moment, rules the Celestial Empire, the dynasty attacked by the present rebels, is a Tungusian dynasty.

Speaking specifically, the present ruling dynasty is Mantshu; but the Mantshu is only one division amongst many. The generic name for the class to which it belongs is Tungusian. It is scarcely a native term—not at least as a collective designation. Some of the particular tribes call themselves *beye* (men); some *donki* (people); but a collective generic name for the whole is wanting. *Tongusian*, however, has arisen out of the word *donki*, which, when adopted by the Chinese, becomes *Tung-chu*.

Some of the Tungusians are subject to Russia, some to China; if, indeed, we may call any members of the stock to which the ruling dynasty belongs by the name of *subject*. The Daourian division lies on the frontier of the two empires.

The name implies this. Daouria means a *boundary*, *border*, or *march;* so that the Daourian Tungusians are the marchmen or borderers of the Russo-Chinese border. Their creed, for the most part, coincides with their political distribution. In China they are Buddhists, like the Mongols; in Russia, imperfect (*very* imperfect) Christians of the Greek Church, and Shamanist Pagans. More of this latter creed survives amongst the Tungusians than amongst the Mongols. No wonder. The Tungusians lie furthest north; so that civilizing influences from the south reached them last. Their alphabet came from the Mongols, as that of the Mongols did from the Uighur Turks, and that of the Uighur Turks from the Syrian Christians. It is only the Mantshu dialect to which this alphabet has been extended. The rest are unwritten. They are numerous.

Some of the Tungusians tattoo their faces. Some occupy an area north of the range of the horse, and within that of the rein-deer. This gives us a division into the *Reindeer*-tribes and the *Horse*-tribes. Lastly, the Tungusians of the extreme north drive *dogs* instead of deer—so that there is a third division founded upon the use of the three different domestic animals. The coldest parts of all Asia lie within the Tungusian area; and in the Tungusian area the hardiest trees disappear soonest. All beyond the tree-line—the line of the birch and willow—is *tundra;* a name implying the absence of trees, along with the preponderance of black bog and moor and cold swamp over the arid levels of the steppe. The steppe is bare and dry; the *tundra* bare and water-logged.

As compared with the nations to the north of them, the Tungusians seem to have been conquerors and intruders.

In more than one place they seem to have pressed forwards between populations originally continuous. Thus some of the populations of the Obi and Yenesey are more closely connected with the tribes of the Indijerka and Kolyma than they are with the interjacent Tungusians of the parts between the Yenesey and the Lena. This looks as if the direction of the Tungusians had been from south to north, probably from the south-east.

The history of the Tungusians begins but late, inasmuch as they lay beyond the pale of Greek, Roman, and Arab intercourse. The Turks came in contact with western nations first; the Mongols next; the Tungusians last. The Chinese histories mention an important tribe called Niuju, which was certainly Tungusian, probably Mantshu. But, even in Chinese history, they play a less prominent part than the Mongols.

The following names, common in maps and travels, are the names of different divisions of the Tungusians—Mantshu, Daourians, Tshapojirs, Lamuts.

The Turks.—The word *Turk* means not only the Turk of Constantinople, but the Turcoman of Turkestan, on the northern frontier of Persia; and it means not only the Turcoman of Turkestan, but all the populations, wheresoever they may be located, and under whatsoever names they may be known, that speak a dialect akin to the Turkish of Rumelia and Anatolia, to the Turcoman of the Persian frontier, and to the Tartar of Independent Tartary. There are good reasons for using the word in this wide sense. In order, however, to avoid confusion, the Turks of Turkey in Europe will be called by the name they themselves use—*Osmanli*, or *Ottoman*.

The Turk stock is one of the widest spread in the world; and we shall see, before long, that it appears in every climate, and under every degree of latitude, from the Arctic circle to the neighbourhood of the Tropics; for we must remember that, although Egypt is not peopled by Turks, it belongs to a Turkish dynasty, so that Turks are to be found on the Nile. In Anatolia (Asia Minor) they are permanent occupants—long settled, and thoroughly acclimated. In Rumelia they have held Constantinople since the fifteenth century. Of Chinese Tartary we know little; but we know enough of the countries of Yarkend and Khoten to know that the occupants are Turks, and that they speak one of the Turkish forms of speech.

It is not so generally known that within the Arctic circle, on the very shores of the Icy Sea, along the frozen Lena, a form of the Turkish is spoken by the Sokhalar or Yakuts, an outlying offset of the great Turk stock in its most northern locality.

The area covered by the Turks is vast; and if the density of the population at all corresponded, the stock would be the most numerous in the world. Independent Tartary alone stretches through more than fifteen degrees of latitude. But the countries which the Turk holds single-handed are but little favoured in respect to climate; whereas Rumelia, Anatolia, Syria, and the more hospitable parts of Southern Asia, were not originally Turk, and contain Turks only as portions of a joint population. Nevertheless, as compared with the Mongol and Mantshu, the Turk stock is a numerous one. Though large, it is by no means complex; *i. e.* it falls into no important divisions, and into no multiplicity of sub-divisions.

The Turk range of altitude is as remarkable as its range of latitude. The table-land of Pamere, 12,000 feet above the level of the sea, is Turk. Except the Tibetan, no Asiatic population lies thus high. There is no want, on the other hand, of low levels occupied by Turks. The main part of their area, however, lies high. Independent Tartary is a steppe. Now to occupy a steppe, generally means to live the life of a herdsman, rather than an agriculturalist, and to dwell in a tent rather than a house. For the Turks of Central Asia, the horse is the domestic animal; for the Yakuts, the reindeer in the southern, the dog in the northern, localities.

The geographical distribution of the Turk stock is itself a history. It speaks to a long series of encroachments, invasions, conquests—sometimes of amalgamation with the conquered populations, and intermixture of blood. This complicates the question as to their natural aptitudes or inaptitudes for particular forms of industry, or for particular kinds of civilization. The Turk, except where he enlarges his area at the expense of some southern population, is removed from the soils that suit agriculture, from the seas that facilitate commerce, from the relations that generate trade, markets, cities. He builds not, neither does he sail; he is not naturally a sower and reaper; he is what the steppe makes him. At the same time there is such a thing as Turk agriculture, *e. g.* in the Crimea, and in the valley of the Jurjan. The Turks of the Jurjan are the Yamud and

Goklan tribes of the Turcomans, and their area is the south-eastern side of the Caspian. Here, where a river favours industry, industry becomes agricultural.

Next to the Arab, the Turk is the most Mahometan family in the world. At the same time the Yakuts preserve much of their old Shamanist Paganism. A few have been converted to the Greek church.

The physiognomy of the Asiatic Turk is modified Mongolian. In Europe, where there has been much intermixture, a change of feature takes place. The beard, especially, increases. Such is the case with the Osmanli; but the Osmanli, it must be remembered, are essentially exceptional. The Turks of Chinese Tartary, the Uzbek Turks of Bokhara, the Turcomans, the Kirghiz of Independent Tartary, the Teleuts, and other Turks of Siberia, are all Mongol in conformation. The Crimea is Turkish in respect to its ethnology, though Russian in respect to its politics.

The Ugrians.—This is the name of the fourth, the most western, and at the same time the most northern of the Turanian stocks. Allowing for the secondary extensions of the great Turk stock, the Ugrians lie in contact with its northern and western boundaries; so that, if we move from Asia to Europe, the Ugrians meet us on the way. Their eastern branch, however, lies due north of the Turks; due north also of some of the Tungusians.

Lapland is Ugrian. The Samoeids are Ugrian. The Yukahiri, at the mouth of the rivers Kolyma, Yana, and Indijirka, are Ugrian. A great portion, indeed, of those populations of the Old World, which lie within the Arctic circle, are Ugrian. The Ugrian family, if not the most American of all the Asiatic families, is second only to the Peninsular stock.

The primary divisions into which this stock falls is that of (1.) the Eastern, (2.) the Western Ugrians.

1. The Eastern are either Samoyeds, Yeniseians, and Yukahiri, all populations of Asia, the Yukahiri being the most eastern; none of these are in contact with each other, inasmuch as northern offsets of the Tungusians and Turks separate them. They are all nomades—all in the *tundra* rather than in the forest.

2. The Western Ugrians consist of the Laplanders, the Finlanders, the Permians, Siranians, and Votiaks of the Russian governments of Perm, Vologda, and Viatka; the Tsheremiss, the Mordvins, the Tshuvash, on the middle Volga; the Voguls and Ostiaks on the ridge of the Ural mountains, and along the rivers Obi and Yenesey, and finally the Majiars of Hungary. Between the extreme types there are broad differences, *e.g.*, between the Laps and Majiars. So there is in respect to their social and intellectual histories.

In regard to physical form the Ugrians are light-haired, rather than dark—many of them are red-haired. This is the first stock where the colour has, in any notable proportion, been other than dark.

The Majiars of Hungary belong to the Ugrian stock—a fact which has long been known to philologues, but which is not sufficiently flattering to the Majiar pride to be willingly admitted. So, however, it is. But as the Majiars are outlyers, having conquered Hungary from the southern part of the Uralian mountains, they lie beyond the true Ugrian area, just as the Osmanli of Rumelia lie beyond the Turk. Laying aside, however, the Majiars, the Ugrian stock extends far southwards, and far westward as well—to Lapland in the latter direction, to the *Mordvin* country in the former. Now, the Mordvins occupy parts of the Russian governments of Kazan, Saratov, Simbirsk, and Tambov; so that the Ugrians extend as far south as the latitude of Lombardy and Piedmont—Northern Italy; thence to the Arctic circle, as aforesaid.

The northernmost portions of the Ugrian area are *tundras*. Here the inhabitants are nomadic, with the rein-deer for their domestic animal. They live, too, in tents. Elsewhere, however, the Ugrian dwells in houses, and tills the soil. The tribual organization grows less prominent as we advance westwards. The steppe gives way to the forest; for alluvial tracts, thickly wooded, are occupied by the various Ugrian populations along the whole of the upper and middle Volga. There are no great mountains in the Ugrian area; the most considerable range being that of the Uralians, between Europe and Asia. These are cold and inhospitable; not because they attain any great elevation, but because they run far towards the north, and lie far inland. Their occupants are the Voguls, a population of hunters in the country of the bear, the beaver, the glutton, and the elk—hunters of the *forest* rather than the *prairie* or open country.

As hunters of the extra-tropical forest, rather than the open country, the Voguls are the most northern tribes in the world—as hunters of game, rather than as fishers. This last is what their neighbours are—the Ostiaks of the rivers Obi and Yenisey. Contrast these two tribes with their neighbours of the south and west—with the Ugrians of the leveller country and the alluvial soils on the Viatka and Kama, and we see the difference between a life of agriculture and a life of venatorial activity. The size of the villages gives us the means of comparison. With the Voguls, the villages consist of some five or ten huts, made of poles, branches, bark, or skins, with a distance between them of not less than ten or twelve miles; so much free space being necessary to the sustenance of the hunter. The Tsheremiss villages number from thirty to forty houses. The Tshuvash are larger still.

The Vogul and Ostiak are undersized, even as compared with the agricultural tribes—not, however, as compared with those of the tundras. Their face is eminently Mongol; so much so, that the eminent geographer Maltebrun has allowed himself to believe that they are a "Kalmuc population, conquered at some far-back period by the Hungarians, who imposed upon them their language." No philologue, however, assents to this. The Voguls are the more Mongol of the two.

The word *Hungarian* introduces a new series of facts. It is to these venatorial and piscatorial Ugrians—these Voguls of the Uralian ridge, and these Ostiaks of the lower Obi—that the Majiars of Hungary are the most closely allied; at least in language. How is this explained? That the Majiars are an intrusive population, who invaded Europe from the north-east, in the tenth century, is a matter of history. That their original country was the southern part of the Urals, is a matter of almost equal certainty. If so, they were the third branch of a Uralian division of the Ugrian stock, whereof the Voguls and Ostiaks were the other two. But their habits have changed. So have those of the Ugrians of Vologda and Viatka, who were once hunters like the Vogul, but are now tillers of the soil like the Finlander and the Esthonian.

To the character of the Majiars of the tenth century, when they won their present quarters, let the old chronicle writers give their testimony. "Out of the aforesaid parts of Scythia did the nation of the Hungarians, very savage, and more cruel than any wild beast—a nation that some years ago was not even known by name—when pressed upon by the neighbouring people of the name of Petshinegs, come down upon us; for the Petshinegs were strong, both in numbers and valour, and their own soil was not sufficient to sustain them. From the violence of these the Hungarians fled, to seek some other lands that they might occupy, and to fix their settlements elsewhere. So they said *Farewell* to their old country. At first they wandered over the solitudes of the Pannonians and Avars, seeking their daily sustenance from the chase, and by fishing. Then they broke in upon the boundaries of the Carinthians, Moravians, and Bulgarians, with frequent attacks. *Very few did they slay with the sword—many thousands with their arrows*, which they shot with such skill from bows made of horn, that it was scarcely possible to guard against them. This manner of warfare was dangerous in proportion as it was unusual. The only difference between the Hungarian manner of fighting and that of the Britons (*sic*) is, that the former use arrows—the latter darts."

Again:—"They never knew the ways of either a town or a dwelling, and they never fed upon the fruits of human labour until they came to that part of Russia which is called Susudal. Till then their food was flesh and fish. Their youths were hunting every day; hence, from that day to this, the Hungarians are better skilled than other nations in the chase."

Looking solely at the physical conditions of his area, and remembering that he belongs to the most northerly group on the face of the earth, we may place the country of the Ugrians amongst the more favoured portions of the extra-tropical world. The oak and lime grow in its southern parts; the fir and birch extend beyond the Arctic Circle in the northern. There is abundance, too, of mineral wealth. Nevertheless, the Ugrian population is scanty, fragmentary, and dependent. It lies between two stocks eminent for their aggressive character—the Turk on the east, the Russian on the west. For this reason there is only one country where the stock is well represented, and that is the Duchy of Finland. In the Duchy of Finland alone, about one-half of the whole Ugrian population is contained. Here and in Esthonia we find the Ugrians, for the first time, in contact with a practicable sea; for the Arctic Ocean, which washes the sea-board of the Laps and Siberians, can scarcely be taken into account as an element or instrument of civilization. But the Baltic connects the western Ugrians with the nations that best represent European civilization—the Germans and the Swedes. Here, though the physical conditions of soil and climate are but indifferent, the social development of the Ugrian stock attains its best development—better, however, in Finland than Esthonia.

The northern Finlanders come in contact with the more southern Laps; the relations between the two divisions being of interest. In language they are liker than in bodily organization and habits. On the other hand, the bodily organization of the Lap is more like that of the Samoyed than is his language. Hence the evidence of the two tests, or criteria—the anatomical and philological—differs.

I believe, however, that the difference is greater in appearance than in reality; inasmuch as, at one time, the Laps were extended much further south than at present, and that on both sides of the Gulf of Bothnia. Thus they covered nearly the whole of Finland, and nearly the whole of Norway and Sweden—some say the *whole*. This was, of course, before the forefathers of the present Finlanders moved northwards, and before the forefathers of the present Norwegians and Swedes did so. As the one encroached, the other retreated. This is the history of the weaker families of mankind all the world over. But this is not all. Wherever two families of strongly-contrasted frames and habits are brought into close geographical juxtaposition, and there is no corresponding change of the physical conditions of their respective areas, there has always been encroachment and intrusion on the one side or the other; on the side of the more southern population of the two when the area is Arctic or Sub-Arctic, or the side of the more northern of the two when the area is Tropical or Sub-Tropical. Now the result of such encroachments is the obliteration of transitional and intermediate forms. That the Findlander *has* encroached on the Lap is a matter of history. That he continues to do so is a matter of observation.

Except the Laps and Finlanders of Norway and Sweden, and the Majiars of Hungary, all the Ugrians belong to the Russian empire; and where their Christianity has come from Russia, they belong to the Greek Church. In Finland and Esthonia, where the influences have been Swedish and German, the creed is Lutheran. With the eastern Ugrians, Paganism is the rule; with the western, the exception. It occurs, however, amongst the Ostiaks, the Voguls, the Votiaks, the Tsheremiss, and the Tshuvash. Of the Asiatic creeds—such as the Mahometanism of the Turks and the Buddhism of the Mongols—there is nothing, or next to nothing, amongst the tribes of this stock.

As the eastern Ugrians are amongst the most American of the Asiatics, the western are amongst the most European.

The Peninsular Stock.—Up to the present time, ninety-nine hundredths of our ethnology has been *continental; i.e.* it has dealt with populations either far removed from the sea, or populations with an inconsiderable and unimportant sea-board. The absolute islanders have been few—very few indeed; few amongst the Monosyllabic, fewer still amongst the Turanian populations. Yet the ocean is one of the greatest amongst ethnological influences. It is important, in even its simplest relations, to the lands it washes. It is important, even if we look upon it merely as a source of a fresh kind of aliment; calling to our minds such denominations as *fish-eaters*, or the more learned term *Ichthyophagi*. It is important if we remember its influence on climate, and contrast the effects upon the human frame of moist and fresh atmospheres, like those of Ireland or New Zealand, with the *cold* and parching winds of the Mongolian steppes, and the *hot* and parching winds of the African deserts.

Far more important, however, is the influence of the ocean as a highway between people and people. It always leads somewhither. As a proof of this, no island, larger than those of the Falkland group, however distant from the nearest point of land, is uninhabited; although, it should be added, that Madeira and Iceland have been peopled within the historical period.

Now the ocean that washes the north-eastern shores of Asia leads from the Old World to the New, and the stock under notice occupies the islands and peninsulas of its Asiatic side.

The divisions of the Peninsular stock are—

1. The *Coreans* of the Peninsula of Corea.

2. The *Japanese* of Japan and the Lu-chu Islands. With each of these divisions the civilization of China has struck root.

3. The *Aino* of the Kurile Islands, extending from Japan to the southern extremity of Kamskatka.

4. The *Kamskadales* of the Peninsula of Kamskatka; a population exceedingly reduced in numbers.

5. The *Koriaks* and *Tshuktshi.*—With the exception of a tract of country along the eastern side of Behring's Straits, and about the mouth of the Anadyr, which is the occupancy of an Eskimo population called *Namollo*, the Koriaks occupy the north-eastern extremity of Asia, bounded on the west by the Yukahiri, and certain Tungusian tribes, and, on the south, in contact with the Kamskadales. In respect to their civilization, they stand in strong contrast with the Japanese. In physical appearance

they have oftener been compared with the American Indian than has any other tribe of Asia.

The extremes of the Peninsular stock lie within comparatively narrow limits. The Japanese are the most civilized, the Koriaks the rudest, the Aino of the Kurile Islands the most insular. These isles are small, and their latitude high; so that their atmosphere is surcharged with moisture. Strange stories are told about the appearance and habits of the Aino. The women are said to take delight in suckling young bears. The men are said to be covered with hair over the whole of the body. Both these statements require further support.

Amongst the Coreans, Siebold, who is our best authority, describes two varieties of physical form. One is eminently Mongol. The other reminds the observer of the European—that is, the face is less flattened, the zygomata less curved outwards, the nose more aquiline. There are also said to be departures from the usual character of the Mongolian hair, as shades of brown and auburn are spoken of.

Few parts of the world are less known than these peninsular localities. Between China, Japan, and Russia, there is plenty of obscurity. The Koriak division, especially, is unstudied.

Koriak is a generic name for a variety of tribes—some in contact with the Ugrian, Yukahiri, some with the northern occupants of Kamskatka. Of those the most important are the Tshuktshi. They preserve their independence of Russia; so that their country can, with great difficulty, be visited. They seem to be a powerful people. They have encroached on the Yukahiri west, and on the Kamskadales south. The Russians are unwilling or unable to interfere much with them. The chief sources of our information are a notice of Matiushkin's in Wrangell's Travels in Siberia, who visited their country from the west, and Lieutenant Hooper's work on the *Tuski* (as he calls the tribe with which he came in contact), descriptive of the populations to the north of Behring's Straits. Their paganism, which extends in an unmodified form through the whole length and breadth of their area, is of the Shamanist kind, so prevalent in Central Asia and Siberia; their social organization complex; their frames and constitutions vigorous. As compared with the Namollos, who rove from place to place with their rein-deers and their canoes, they are stationary, and by this name they are often distinguished.

A *stationary Tshuktshi* is a Koriak; a *rein-deer Tshuktshi*, a Namollo. Confusion, against which we should guard ourselves, has arisen from these equivocal terms.

The parts under notice lead us towards America. So do the populations. Yet America will stand over for a while, since our notices of Asia require completion.

The next group has a somewhat cumbrous denomination. We must, for the present, call it *the Caucasian, in the limited sense of the term.*

We must use this roundabout form of expression, because, from the time of Blumenbach downward, the word has had a double sense—a narrower, and a wider one.

In its narrower sense, *Caucasian* means the populations between the Black Sea and the Caspian, the populations of which the mountain range of Caucasus is the occupancy. The English and French politicians understand well what is meant by the term. The Russian understand its meaning even better. It means those tribes who, like the Circassians, give so much trouble to the Russian generals, and defend their frontier so successfully; those tribes who fight under Shamyl for a leader. It means, too, the softer and more reducible Georgians, who are good and tractable subjects to the Czar. It means these and the allied populations, all of whom are more or less mountaineer, and all of whom lie within the region of Caucasus. It does not, however, mean the Turks and Russians to the north, nor yet the Persians to the south and east; though we must remember that all these populations are in the neighbourhood. This is the limited power of the word *Caucasian*.

In its wider sense the term comprizes, along with *most* of the populations denoted by its more restricted signification, a vast and heterogeneous multitude of tribes, families, and stocks. In its wider sense it comprises the Greek, the Indian, the Italian, the German, the Pole, the Frenchman, the Persian, the Englishman, the Welshman, the Irish Gael, the Scotch Gael, the Manksman, the Jew, the Arab—a wide range this—an important class this; an important class, *if real*.

In the language of Blumenbach and Cuvier, and, to a certain extent, in that of Prichard also, the *Caucasian* includes the inhabitants of the continental parts of the Old World, which are neither Mongolians nor Negroes, in their physical conformation. How came the term to be chosen? When Blumenbach investigated *crania*, the best-shaped skull in his museum was that of a Georgian. It was so well shaped, according to the European standard, that he made it the type of his second class, just as he made a Mongolian the type of his first. And just as he used the term Mongolian in a wide as well as a restricted sense, did he, in like manner, use the term Caucasian. Experience has shown that it was not well chosen.

So much for the *verbal* question as to the *name of a particular class*. The *real* question, as to the truth and accuracy of the class itself, is another matter. How is it that the word *Mongol* holds its ground, whilst *Caucasian* will have to be abandoned. *Mongolian* has two powers—*Caucasian* has no more. Yet the practical difficulty of distinguishing between the *Mongolian of Mongolia* (or the Mongolian in the limited sense of the term), from the *Mongol* of the great *Mongol* class, has never been so great as to endanger the use of the double term.

The answer to this lies in the fact that *the class called Caucasian is not a natural one*. It is founded upon *negative* characters, quite as much as upon *positive* ones. A skull which approached that of Blumenbach's Georgian, was Caucasian; but a skull was also Caucasian, if it were, at one and the same time, a skull from the continental parts of either Asia or Africa, and a skull that belonged to neither a Mongol nor a Negro. Classifications of the kind are rarely satisfactory—rarely permanent. The Mongol class was natural as far as it went; *i. e.* none of the populations included in it were misplaced. It did not, indeed, include all that it should have done; but this was a matter easily rectified. So the term *Mongol* keeps its ground.

The Caucasian class was faulty in the opposite direction. It included more than one population that no single class of like value should have included. It included the Arab, who was in a different category from the western European, and it included the western European, who was in a different category from the Caucasian of Caucasus.

The great bulk of this wide and general Caucasian class, or family, consisted of the Europeans of western and southern Europe, the civilized nations of the world. So that *Caucasian* became one of the complimentary terms in Ethnology. Greek art was Caucasian; Roman jurisprudence, Caucasian; Jewish monotheism, Caucasian; Anglo-Saxon freedom, Caucasian; the American institution of slavery, Caucasian; and even French fashions and German philosophy were Caucasian. From all this it soon followed, that *the least Caucasian of the great Caucasian races, so called, were the natives of Mount Caucasus itself.*

GROUP III.—The Caucasian Stock in the limited meaning of the term—(Dioscurian—*Latham*).—***Physiognomy*:** European, rather than Mongol.—***Language*:** Monosyllabic rather than European.—***Area*:** Caucasus.—***Divisions*:** 1. The Circassians. 2. The Mizhdzhedzhi (Mizhjeji). 3. The Irôn. 4. The Georgians. 5. The Lesgians. 6. The Armenians.

Each of these groups falls into sections and sub-sections; although, as may be expected, they are not all equally complex. Nevertheless, the fact of their being divided and subdivided at all, is one of great importance. The classes are numerous; yet the area is small, and, as compared with such vast masses of country as the Turk or Ugrian superficies, absolutely insignificant. At the same time it is broken up into impracticable valleys and isolated fastnesses—conditions that favour the formation of separate and independent communities.

We must take care, then, that whilst we bear in mind the important fact of there being considerable differences between the different sections of the stock before us, we do not forget the physical phenomena that favour their evolution. Neither must we forget that there is likeness as well as difference—similarity as well as points of contrast.

There is difference as well as likeness,—likeness as well as difference; and it is not difficult to distribute the points of the two. The likeness between the mountain tribes of Caucasus lies in their habits, temper, and physical conformation rather than in their language: the difference in their language rather than in habits, temper, and physical conformation. A great deal has been written about the extent to which one tribe is unlike another; but it is upon the prominent, well-known, and long-ascertained distinctions of dialect and language that this dissimilarity has been calculated. Had the modes of speech been as uniform as the manners and customs, less would have been said about the multiplicity of tribes and nations occupant of the Caucasus. I do not say that the whole population would have been included in a single class. I only say that less would have been said and written about the peculiarities of Caucasian ethnology.

As the points of difference have commanded the most attention, let us give them a conspicuous place. The ancients had to regard them. Gibbon, quoting Pliny, states that in the market-place of one of the Colchian towns,* Dioscurias, no less than one hundred and thirty interpreters were necessary for the transaction of business. Allowing for exaggeration, let us halve the sum. Then let us halve the remainder, on the doctrine that a moiety of the men of business were Greeks, Armenians, Syrians, and other nations foreign to Caucasus. The remainder will still be considerable.

Modern researches have confirmed rather than weakened the impression left by the references in Gibbon. The first collectors of Caucasian vocabularies were surprised at the number of what they reasonably (and, perhaps, rightly) considered to be mutually unintelligible forms of speech. The general philologues who came after them, and worked in the way of the arrangement and classification, still admitted the variety of tongues. It ended, however, in the establishment of the five primary groups named at the beginning of the notice; not counting the Armenian, which no one but the present writer makes Caucasian.

But this was not all. Whatever might be the extent to which the Caucasian forms of speech differed from each other, they differed in a still greater degree from those of the contiguous countries. For the northern frontier this was not surprising, since there had been large conquests and corresponding displacements in the Russian governments of Caucasus, Astrakhan, and the Don Kosak country. The Turks had overrun those parts—so had the Russians. No wonder, then, that the line of demarcation on the northern frontier was clear, broad, and trenchant. Everything that tended to obliterate such transitional and intermediate varieties as might once have existed, had taken place. On the south, however, things were different. Armenia and Kurdistan were each such tracts as Caucasus itself, the probable occupancies of old and primitive populations, retentive of old characteristics, representatives of a long line of ancestors. Armenia and Kurdistan, it might reasonably be imagined, should resemble Georgia and Circassia.

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* On the strength of this, the present writer has suggested the term *Dioscurian* for the class.

They did to a certain extent; but not to the extent that philologues expected *à priori*. The Armenian language was a long time before it took a place in any philological class at all; and when it did so, it was not in the class that contained the Georgian, its next door neighbour. To the east and west lay the Black Sea and the Caspian.

All this helped to isolate the Caucasians in *the limited sense of the term;* the points wherein they most especially differed, both from each other and from the contiguous populations, being points of language.

Let us now turn to the consideration of their physical conformation. We have heard that, comparatively speaking, it is pretty uniform throughout Caucasus. How is it in respect to that of the populations around?

The physical conformation of the Caucasians, in the limited sense of the term, is dissimilar to that of the populations on the northern, but not so dissimilar to that of the populations of the southern, frontier. In other words, it is more Armenian and Kurd than Tartar or Ugrian. It is in the south where the displacement of the originally contiguous tribes has been smallest. This leads us somewhat in the right direction for the Caucasian affinities.

We are led further, when we discover that the difference between the tongues of Caucasus on the one hand, and of Armenia and Kurdistan on the other, has been exaggerated. Some of the latest works on this subject have placed the Georgian and Armenian in the same class.

The present writer agrees with this arrangement. He agrees to the doctrine of the Georgian and Armenian being in one and the same philological division. But he denies that this division is the one wherein the Armenian was originally placed. He, consequently, takes exceptions to the transfer. He would retain the language that others remove; remove the one that others propose to retain. The Georgian he would keep as it is—Caucasian. The Armenian he would *not* keep as it is; *i.e.* in the same class with the Latin, Greek, German, and Sarmatian. The approximation of two tongues is admitted on both sides. The only question is, Which is to be shifted? "The Georgian," say the later investigators, Bopp and others, "is more akin to those Asiatic tongues which show European affinities than it has hitherto been considered to be."

"The Asiatic tongues," says the present writer, "which at one and the same time have European affinities and are akin to the Georgian, are more Caucasian in the limited sense of the term than the current classification makes them."

Of the Asiatic tongues, with real or supposed European affinities, one (the Armenian) is spoken to the south of Caucasus rather than in Caucasus itself. The other, in respect to its locality, is absolutely Caucasian. It is the Irôn, or (as it is oftener called) the Ossete. It has been mentioned by name, in order that the present state of opinion may be further illustrated. For upwards of forty years—ever since the publication of Klaproth's "Asia Polyglotta"—it has been admitted to be what is called Indo-European; *i. e.* to stand in the same class with the Latin, Greek, German, and Sarmatian. Now the syllogism that explains the views of Bopp and others runs thus:—

The Irôn is Indo-European, as opposed to Caucasian in the limited sense of the term—

The Georgian is what the Irôn is—

The Georgian is Indo-European as opposed to Caucasian in the limited sense of the term.

For this the author would substitute—

The Georgian is Caucasian in the limited sense of the term, as opposed to Indo-European—

The Irôn is what the Georgian is—

The Irôn is Caucasian in the limited sense of the term, as opposed to Indo-European.

But this, after all, may be a mere matter of words; inasmuch as the *opposition* between the words *Caucasian* and *Indo-European* may be unreal, or immaterial. The possibility of this being the case brings us to the investigation of our *facts*. These lead to a wholly different series of affinities; affinities incompatible with the existence of the Armenian and Irôn as Indo-European tongues, and the supposed difference between such groups as the Indo-European and Monosyllabic.

If the Georgian be Indo-European, the Chinese and Tibetan are Indo-European also. But this means that anything or everything may be Indo-European; in other words, that the term means so much as to mean nothing.

The closest affinities of the Caucasian tongues are with those of the monosyllabic class. But though this is a fact, it should be added that the known number of scholars who believe in it is small—

> "Numero vix totidem quot
> Thebarum portas vel divitis ostia Nili."

Yet the affinities of tongues, like the Circassian and Mizhdzhedzhi, are not exactly everybody's subject; so that, small as is the number who hold by the doctrine before the reader, it may, nevertheless, contain a fair proportion of the competent judges. At any rate, Mr. Hodgson, of Nepal, is one of them. A paper of his, in the "Transactions of the Asiatic Society of Bengal," and a table* of the present writer's, supply the chief published *data*.

The affinities of the Caucasian languages are Monosyllabic. This is the first material fact we have met with. Lengthy as the foregoing disquisition has been, for a work like the present, it has dealt with *names* rather than phenomena. It has also given more to unlearn than to learn.

But, though the philological affinities of the Caucasian tongues are monosyllabic, the physical conformation of the Caucasian men and women is by no means either Chinese or Tibetan, Siamese or Burmese. It is not that of the Monosyllabic populations at all.

The physical conformation of the mountaineers of Caucasus is akin to that of the Persians, and the higher castes of India; it is also, as contrasted with that of the populations who speak the Monosyllabic tongues, akin to the conformation of the Greeks and Italians; *i. e.*, it is like that of the Southern Europeans rather than the Northern;

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* "Varieties of Man," p. 123.

Central, and Eastern Asiatics. It is *Caucasian* in the wide and loose sense of the term. Not that the current opinions on these points can be taken without any reserve,—the opinions that look for the chief models of female beauty and manly strength amongst the proverbially fine populations of Georgia and Circassia.

There is some exaggeration here. As compared with their neighbours on the side of Russia—as compared with their neighbours on the side of Turkey, the populations under notice are handsome and well-formed; and, as there is a vast traffic in female slaves for the harems of the Ottoman Turks, the best samples of the two populations find their way to Europe. From these the rest are judged. Again, the Circassian warriors represent the Caucasians of the north-west; and it is upon them that our ideas of the Circassian conformation are based. But Circassia (and this must be borne in mind) is a land of *castes*—of high-caste nobles and of low-caste plebeians. It is a land of caste and feudalism; war being, at one and the same time, the occupation of the nobles, and the means by which the greatest number of individuals are brought in contact with the nations of Europe. The evidence of those who have formed their opinions from residence in Caucasus rather than from the slave-markets of Constantinople is by no means over-favourable. Pallas (as quoted by Prichard in his "Natural History of Man," p. 254) writes that the men, "especially amongst the higher classes, are mostly of a tall stature, their form being of Herculean structure. They are very slender about the loins, have small feet, and uncommon strength in their arms. They possess, in general, a truly Roman and martial appearance. The women are not uniformly Circassian beauties; but are, for the most part, well-formed, have a white skin, dark brown hair, and regular features." He adds—"I have met with a greater number of beauties among them than in any other unpolished nations."

This is the language of fair and moderate encomium. Reineggs, however, so far denies their claim to superior beauty as to write that he knows not "what can have given occasion to the generally received prejudice in favour of the female Tcherkessians. A short leg, a small foot, and *glaring red* hair, constitute a Tcherkessian beauty."

The main *differentiæ*, however, of their organization lie in the statements of Klaproth—viz., that they have "long faces, and thin and straight noses."

Again, he writes that the Abassians, a tribe of the Circassians, are "distinguished by narrow faces; heads compressed at the sides; by the shortness of the lower part of their faces; by prominent noses, and dark brown hair."

This narrowness and compression of face, and this prominence of feature, give us the main points in the anatomy of the Caucasian skull. The nasal bones, instead of being depressed, are elevated, and the zygomata are straight and narrow instead of curving laterally outwards.

There is no denying that these are important modifications of structure; at the same time, they are by no means so great as they appear to be when we measure them from their effects on the features. A little difference of elevation, a slight change in curvature, convert a flat and broad into a compressed and prominent physiognomy.

At the same time, the fact of the evidence of language, and the evidence of physical form, indicating a different range of affinities in the case of the Caucasian or Dioscurian populations, must be admitted, and it must be admitted as an ethnological difficulty. The principle that helps us in the explanation of it is the following:—

Physical and philological changes may go on at different rates.

A thousand years may pass over two nations undoubtedly of the same origin; and which were, at the beginning of those thousand years, of the same complexion, form, and language.

At the end of those thousand years there shall be a difference. With one the language shall have changed rapidly, the physical structure slowly.

With the other the physical conformation shall have been modified by a quick succession of external influences, whilst the language shall have stayed as it was. Hence—

With an assumed or proved original identity on each side, the difference in the rate of action on the part of the different influences is the key to all discrepancies between the two tests. The language may remain in statu quo, *whilst the hair, complexion, and bones change; or the hair, complexion, and osteology may remain* in statu quo, *whilst the language changes.*

Apparently this leaves matters in an unsatisfactory condition; in a way which allows the ethnologist any amount of assumption he chooses. Apparently it does so; but it does so in appearance only. In reality we have ways and means of determining which of the two changes is the likelier.

We know what modifies *form*. Change of latitude, climate, sea-level, conditions of subsistence, conditions of clothing, &c., do this; all (or nearly all) such changes being physical.

We know, too (though in a less degree), what modifies *language*. New wants gratified by objects with new names, new ideas requiring new terms, increased intercourse between man and man, tribe and tribe, nation and nation, &c., contribute to this end.

Still there is a good deal to be accounted for,—more than our present limits allow us to enlarge upon.

The Circassians.—The division of the Caucasian (in the limited sense of the term) populations, which it is convenient to begin with, is the *Circassian*, or, as the Russians call them, the *Tsherkess*. As far as the few researches, hitherto made upon the subject, go, it is the Circassian dialects that are the most evidently Monosyllabic in character. It is also the Circassian in which the greatest amount of relationship to the languages of Tibet, and the western parts of the Monosyllabic area, have been found; as may be seen by the important paper of Mr. Hodgson's, already alluded to. The elementary sounds of the Circassian are harsh; consonants are accumulated; hiatus are frequent. The declension is poor. There is not even a sign for the possessive case. Thus, in the Absné dialect, *ab = father, ácĕ = horse; ab ácĕ = father's horse;* (verbally, *father horse*). In expressions like these, position does the work of an inflection.

Judging from Rosen's example, the use of prepositions is as limited as that of inflections, *sara s-ab ácĕ ist'ap = I my-father horse give*, or *giving am; abna amus'w izbit = wood bear see-did = I saw a bear in the wood; awinĕ wi as'-wkĕ =* (in) *house two doors; ácĕ sis'lit =* (on) *horse mount-I-did.*

Hence declension begins with the formation of the plural number. This consists in the addition of the syllable *k'wa.*

Acĕ = horse; ácĕ-k'wa = horses.
Atsla = tree; atsla-k'wa = trees.
Awinĕ = house; awinĕ-k'wa = houses.

In the pronouns there is as little inflection as in the substantives and adjectives, *i.e.* there are no forms corresponding to *mihi, nobis,* &c.

1. When the pronoun signifies possession, it takes an inseparable form, is incorporated with the substantive that agrees with it, and is *s*- for the first, *w*- for the second, and *i*- for the third person singular. Then for the plural it is *h*- for the first person, *s‘*- for the second, *r*- for the third: *ab* = father;

S-ab = *my father;* *h-ab* = *our father.*
W-ab = *thy father;* *s‘-ab* = *your father.*
I-ab = *his (her) father;* *r-ab* = *their father.*

2. When the pronoun is governed by a verb, it is inseparable also, and similarly incorporated.

3. Hence the only inseparable form of the personal pronoun is, when it governs the verb. In this case the forms are:—

Sa-ra = I. *Ha-ra* = we.
Wa-ra = thou. *S‘a-ra* = ye.
Ui = he. *U-bart‘* = they.

The verbs are not quite so simple. Thus the root for the verb *ride* is *c'wisl.* From this we have c'wis‘l-*ap*, *I ride;* c'wis‘l-*oit*, *I am riding;* c'wis‘l-*an*, *I was riding;* c'wis‘l-*it*, *I have ridden;* c'wis‘l-*chén*, *I had ridden;* c'wis‘l-*ast*, *I shall ride.* The persons are—

Singular.

1st person, *sara s*-c'wis‘l-*oit* = *I am riding.*
2nd „ *wara u*-c'wis‘l-*oit* = *Thou art riding.*
3rd „ *ui* *i*-c'wis‘l-*oit* = *He is riding.*

Plural.

1st person, *hara ha*-c'cwis‘l-*oit* = *We are riding.*
2nd „ *s'ara s‘*-c'wisl-*oit* = *Ye are riding.*
3rd „ *ubart r*-c'wisl-*oit* = *They are riding.*

It is in Circassia where the feudal structure of society is the most strongly marked, and where the relation between the *vorkh*, or *noble*, and the *pshi*, or *retainer*, is the closest. The Circassians, too, are most in the habit of selling their daughters to the harem-masters of Constantinople and Egypt; a habit by no means laudable, but still very different from ordinary slave-dealing. If a Circassian maiden stays at home, she is *sold* in marriage to one of her own countrymen, of whom she, probably (but by no means necessarily), knows something beforehand. If shipped to Constantinople, she is sold to a foreigner, necessarily unknown. On the other hand, the stranger Turk is almost certain to be a wealthier man than the Circassian fellow-countryman.

The divisions of the Circassians are pretty distinctly marked by their dialects; *e.g.* there is the form of speech spoken on the *northern* slope of the mountains, and along the river Kuban. This is that of the proper Circassians, Tsherkess, or, as they call themselves, *Adighé*. Then there are the allied tribes of the *southern* slope, and the sea side. These are the Abassians. Thirdly come the *eastern* Circassians, whose occupancies are on the water-system of the *Terek* rather than the *Kuban*, and who inhabit the Great and Little Kabardah. But beyond these there are several more obscure and isolated populations, resident in the more impracticable parts of their forest-cinctured mountain-range. Nevertheless, the three chief divisions are those of—*a*, the Abassians; *b*, the Kabardinians; *c*, the Adighés.

But it is only the upper part of the Terek that belongs to the Circassian area. The head-waters of its *middle* feeders—almost all of which come from the southern side—lie in the country of

The Mizhdzhedzhi, or *Tshetshentsh*, whose dialects separate them from the tribes around them, but of whom little is known besides.

Equally central with the Mizhdzhedzhi, equally removed from contact with either the Caspian or the Black Sea, equally on the head-waters of the Caucasian rivers, are—

The Iron.—So central are these, that they occupy the watershed between the Terek and Kuban on the north, and the Kur on the south, overlooking the wide valleys of Georgia, as well as touching the mountain defiles of the Tshetshentsh. Their language falls in two (probably more) well-marked dialects. Their creed is an imperfect Christianity of recent origin; their allegiance (like that of the Georgians rather than the Mizhdzhedzhi, and the Circassians) Russian.

The Russians call them *Ossete*, and by this name they are best known. *Irôn*, however, is the native one. Much has been written about them and their language, which is certainly more like the languages of the so-called Indo-European class than the others of the Caucasus. Indeed it is the Irôn form of speech, upon which so much of what has formed the preliminaries to the class under notice turns.

The Georgians.—The Kuban was the chief river of the Circassians; the Circassians the chief population of the Kuban. The Georgians are the same in respect to the Kur. The valley of the Kur is the favoured part of Georgia—the province of Kartulinia, of which Tiflis is the capital. But there is a good deal of Georgia which is no fruitful valley, but (on the contrary) a rude and rugged mountain range. These are the countries of (*a*) the Mingrelians, (*b*) the Imeritians, (*c*) the Swani. Finally, the descendants of the ancient Colchians, who extend along the southern shores of the Black Sea as far as Trebizond, who are subject to the Ottoman empire rather than to Russia, who are Mahometans rather than Christians, and who use the Arabic alphabet rather than the Kartulinian, are Georgian, as is shown by their language.

At one time the Georgian language probably extended far over the northern portion of Asia Minor. It has, however, been encroached upon by the Turkish.

The Georgians are the most civilized of the Caucasians; the Mizhdzhedzhi possibly the rudest. The Georgians, who received their Christianity from Armenia, have retained it. Their alphabet, too, is of Armenian origin, though (from the fact of its letters being changed from a square and angular to rounded and oval contour), considerably modified and disguised.

The religious and civilizational history of the other tribes is, roughly and generally speaking, as follows:—

a. There was first the original paganism, which, at present, in its original and unmodified form is, perhaps, extinct. At the same time, there can be but little doubt that, when the country becomes better known, we shall find it showing itself transparently through the creeds that have displaced it.

b. Then there was an imperfect Christianity diffused from Syria and Armenia. Except in Georgia this has given way to

c. An irregular Mahometanism, which

d. In the Irôn country is being attacked by the Russian missionaries. Speaking generally, however, we may predicate of the Caucasus that the Russian parts are Christian; the independent, Mahometan.

The Lesgians belong to the latter class, and are the most important members of it; more so than even the Circassians. They are the most eastern of the Caucasians, stretching from the shores of the Caspian to the Tshetshentsh and Irôn frontiers. Their area seems to have been encroached upon on the south and east; inasmuch as a wild population of the province of Ghilan, on the south side of the Caspian, called *Talish*, is considered to be Lesgian in blood, though, at present, Persian in language.

Daghestan is the country of the Lesgians; and the Avar, the Anzukh, the Tshari, the Andi, &c., are the chief Lesgian dialects. The prophet warrior, Shamyl, is no Circassian, as is currently supposed, but a Lesgian.

The Armenians, lying south of Caucasus, rather than in Caucasus itself, were the first of the group to be civilized, to use an alphabet, and to be converted to the Christian religion. Their contiguity to Syria did this. Unlike the other members of their class, the Armenians are spread widely over the world—in Turkey, in India, in Russia—as merchants and bankers.

The Armenian is in geographical contact with Kurdistan, or the country of the Kurds, a population which belongs to

GROUP IV.—THE PERSIAN STOCK.—*Physiognomy:* Caucasian rather than Mongol.—*Language:* in its present state with but few inflections.—*Area:* Kurdistan, Persia, Afghanistan, Biluchistan, parts of Bokhara, the Kohistan of Cabul, Kafiristan.—*Divisions:* Kurds, Persians, Biluchi, Afghans (Pushtu), Paropamisans (populations of Kafiristan and the Kohistan of Cabul).

The greater prominence of feature, and the comparative narrowness of the zygomatic space, which contrasted the Caucasian with the Turanian and Monosyllabic groups, are found throughout Persia. Meanwhile, the colour of the skin darkens, but not to such an extent as to create difficulties. Almost all the Caucasian area is wood and mountain; the greater part of the Persian, a table-land—with an extreme temperature.

The language creates the chief difficulties in the classification. There are but few inflections in the Caucasian tongues. There are also but few in the Persian. So far the two classes agree. But what if this want of inflection arise from a different cause in each? In such a case the similarity is unreal. Nay, it becomes converted into a difference. Now such may be the case. The Persians may have had inflections and lost them: the Caucasians may be without them, because they have never been developed.

So far from this being a mere hypothetical complication, it is one which the majority of scholars believe to be a real fact. It will, however, be better investigated when we have gone over the whole of the groups. It is noticed at present, in order that it may be compared with the questions indicated in the consideration of the last group. There is doubt amongst philologues. There is doubt as to the way in which the Caucasian and Persian groups are allied. That they *are* allied is admitted. But the question is, whether the Caucasians are Persian, or the Persians Caucasian. It has already been stated that this is no mere verbal question, and the further we proceed, the more we shall see of its reality and importance.

Like the Turk and Arab, the Persian is one of the three great Mahometan families of the world—the original creed, for a great part at least of its area, having been that of the Zoroastrian fire-worshippers,—a creed still existent amongst the Parsees. Nor has Christianity always been foreign to the stock. It is reasonably believed that the missionaries, who preached the gospel of the so-called St. Thomas's Christians in India, were Persian; Syria having been the remoter source. Indeed the geographical contiguity of Persia to Syria, Assyria, Babylonia, and Arabia, is the main point in the analysis of the elements of Persian civilization. No stock we have hitherto met with has, at one and the same time, been so closely in contact with the populations of the Euphrates, the Nile, and the Mediterranean on the one side, and those of India on the other.

So exposed has Persia been to foreign influences, that it is only in one remote district that the population is other than Parsee or Mahometan, modified and mixed. This is *Kafiristan*, or the *Land of the Kafirs* (*infidels*); an impracticable mountain-country on the watershed between the Oxus and the north-western system of the Indus. No European, and but one or two Mahometans, have visited the country. The following account, from Elphinstone's "Caubul," is the only one there is of this important population—important because, comparatively, unmodified in the midst of a stock eminent for the heterogeneous nature of the numerous influences that have acted on it.

Mullah Nujeb, the traveller, whose account Mr. Elpinstone has given us, found the valleys of the Kafiristan mountains well-peopled, each being occupied by a separate tribe, family, or settlement. The proper term is doubtful, since, although the Kafirs are said to be divided into tribes, it is added that these are geographical rather than genealogical. If so, they are scarcely to be called *tribes* at all. Each valley, however, has its own proper population, and it is the occupancy of these respective valleys that gives rise to the different names of the different divisions. Mullah Nujeb's list supplies the following names; and herein we may notice the frequency of the termination *je*, its similarity to the Pustu *zye*, and the consequent compound character of the words wherein it occurs — Caum-o-*ji*, Kest-o-*ji*, Múndegul, Cam-to-*ji*, Purune, Tewni, Púnúz, Ushkong, Umshi, Sunnú, Kulume Rúse Turkuma, Nisha, Chumga, Waui, Khúllum, Dimish, Iráit, &c. Everything here is particular and specific; neither is there any general name for the Kafir population at all.

The name just applied is Mahometan. A Kafir is an infidel, and Kafiristan is the infidel's country; so that the term is simply that of a religious sect designated from its negative characteristics. And it is inconvenient, since the populations of the neighbourhood are akin to that of the Kafirs, but are not other than Mahometan. Another name—or rather a pair of names, as little native, however, as the one just noticed—is suggested by their dress. One division of them is called the *Tor* Kafir, or *Black;* the other the *Spin* Kafir, or *White* Infidel. *Siaposh*, too, which means *Black-vested*, is a synonym to *Tor* Kafir. It must be repeated that it is their dress and not their complexion that has suggested these names. Some wear a vest of black goat-skin, others a dress of white cotton: all, however, are *light-complexioned*. Their roads, which are only fit for men on foot, are continually crossed by ravines and torrents, over which swinging bridges are thrown. Their villages rise along the slopes of the hills in terraces; so that the roof of one house forms the street to the one above it—such, at least, is the Mullah's description; and these villages are numerous. The Caumoji had ten such; and Caumdaish, the largest of them, contained five hundred houses.

At Caumdaish, Mullah Nujeb obtained some insight into their religion. There was the belief in a single god, whose name was Imra, a name re-appearing in the Hindu Pantheon. But there were idols besides,—idols which represented departed heroes,—heroes who, if properly propitiated, would intercede with Imra on behalf of their worshippers. Sometimes male, sometimes female—sometimes on horseback, sometimes on foot—of wood or stone, as the case might be—these objects of adoration were common about Caumdaish. In the public apartment, too, of that village was a high wooden pillar, on which sat a figure with a spear in one hand and a staff in the other. It represented the father of one of the magnates of the village, who had earned the privilege of setting it up by a series of feasts given to the whole community. Hospitality, in general, is one of the cardinal Kafir virtues, by the due exercise of which an admission to *Burri le Bula*, the Kafir Elysium, is most effectually insured. The opposite to Burri le Bula is *Burri Duggur Bula* (Hades, Tartarus).

These individual apotheoses prepare us for an almost infinite variety in the Kafir Pantheon. When honours are local, the hero-worship will vary with the valley or village; and such is really the case. In Caumdaish the chief deities are as follow:—

1. Bugish, the god of the waters. 2. Mauni, who expelled Yúsh, the Evil Principle, from the world. Compare the Indian term Menu. 3. Murrur. 4. Urrum. 5. Pursú. 6. Gésh. 7-13. Seven brothers, named Paradik (compare Paradise), who had golden bodies, and were created from a golden tree. 14-20. Puron; seven golden brothers of the same kind. 21. Kumye, the wife of Adam. This is, perhaps, the Mullah's view rather than that of the Caumdaish people themselves. 22. Dissauni, the wife of Gésh. 23. Dúhí. 24. Surijú. 25. Nishtí.

One of the sacrifices at Caumdaish was witnessed by Mullah Nujeb. It was to Imra, and was celebrated at a particular place near the village where there was a stone post. Before this a fire was kindled, and, through the fire, flour, butter, and water were thrown on to the stone. Then an animal was sacrificed, and its blood, like the flour and butter, thrown through the fire. The flesh was partly eaten—partly burnt. One of the prayers was for the extermination of the Mussulmans. The worship of idols is performed nearly in the same way. Sometimes, however, instead of the open air, they are performed in houses called Imra Umma. Fire, though essential to all of these sacrifices, is not itself an object of veneration; neither is any eternal fire kept up. Its chief fuel is the branch of some particular, though unknown, tree. The priests, though hereditary, have no great influence; neither have another class of religionists, who have the credit of procuring the inspiration of some superior being by holding their heads over the smoke of a sacrifice. Fish is the only aliment from which they abstain; beef, and all the other kinds of animal food, being eaten indifferently. There seems to be certain fixed days for festivals, on one of which they throw ashes at each other. There is always sacrifice on these occasions, and always feasting. At one of them the boys light torches of a sort of pine, and carry them before one of the idols, where they throw them down, and allow them to burn. At another, the women hide themselves without the village, and let the men search for them. When found, the women defend themselves with switches, but are finally carried off.

When a child is born, it is carried with the mother to a house, built for the purpose, beyond the precincts of the village, where, for twenty-four days, they remain—the woman, for so long, being considered impure. When this is over, both mother and child are bathed, and they return to the village, accompanied by dancers and musicians. At naming, the child is held to the breast, whilst the names of its ancestors are repeated; and the one which is being pronounced, when the child begins to suck, is the one that the child takes.

Between twenty and thirty the men marry, and between fifteen and seventeen, the women. The bridegroom sends some clothes and ornaments to the bride—also some of the materials for the marriage feast. The feast is continued through the night, and the next day the bride, dressed in the finery that the bridegroom had sent her, is taken away by him. The father adds some article of dress to the equipage of the bride, and gives the husband a cow, or perhaps a slave. The girl is then led out, with a basket on her back, containing fruits and walnuts, prepared with honey, and (when it can be afforded) a silver cup. The whole village attends her, dancing and singing. The price for the bride is paid to the father a few days afterwards. Sometimes it amounts to as many as twenty cows. The priest has no share in all this. Polygamy is allowed—adultery but moderately punished; and the women move about free and unveiled. They do all the domestic, and some of the agricultural, work.

When a Kafir dies, he is dressed in his best clothes, and extended on a bed, with his arms beside him. The body and bed are then carried about by his kinsmen, whilst the attendants at the funeral dance, sing, and perform a sham fight around it. The women, meanwhile, lament. From time to time, too, the body is set down, and then the weeping that takes place is over. At length it is shut up in a coffin, and deposited *above* ground. A feast follows all funerals, and once a-year there is a festival in honour of the deceased, when some food is laid out for his manes.

A visitor of condolence, when he enters the house of his afflicted acquaintance, throws his cap on the ground, draws his dagger, seizes the mourner by the hand, pulls him up, and forces him to join in a dance round the room. The rich wear their best clothes, and some put on black fillets, ornamented with shells—one for each Mussulman killed by the wearer. The few leagues which are struck with the Mussulmans are attended with the ceremony of killing a goat, dressing its heart, biting off one half, and giving the other to the Mussulman.

They dance vehemently to a quick and wild music of the tabor, the pipe, or the the voice; and this is the chief amusement. They sometimes form a circle of men and women alternately, who move round the musicians for some time with joined hands, and then they all spring forward, and dance together.

Their wooden houses generally contain a cellar for the cheese, clarified butter, wine and vinegar, with a low-backed bench fixed to the wall. More remarkable, however, are their seats. These are stools, shaped something like drums, but drawn in, in the middle; and the tables are like them, only larger. The stools are of wicker, but the beds are wood. A Kafir, when sitting on the ground, stretches his legs like a European. This, combined with the use of chairs or stools, is one of the points which strikes their neighbours as eminently characteristic. So does their use of wine. Of this they have three kinds, of which both men and women drink freely.

Saving the savage character of their warfare, the Kafirs are described as a sociable, kind-hearted people—pre-eminent for hospitality. The people of a village come out to meet a stranger, ease him of his baggage, carry it for him, and receive him with warm welcomes. Every man of note expects to be visited by him, and is prepared, accordingly, to press upon him food and drink.

The constitution of a Kafir community is uncertain. Such regular magistrates as exist have but little power. On public matters the wealthier consult together. The *lex talionis* is the more prominent part in their law. Titles of their own they have none—that of Khan, applied to the rich men, being of a Pushtu origin. Cattle and slaves are the chief elements of their wealth.

Two of those black goat-skins, from which the Siaposh take their name, make the vest, and two more the petticoat of the Kafir—the hair being on the outside. Bare-armed and shaven-headed, the Kafir has but a long tuft on the crown of his head, and two curls over the ears. There is some difference, however, in respect to head-gear, if he have killed a Mussulman. The hair is plucked from all parts of the face but the chin. This is well-bearded.

The women dress much like the men; the chief differences appertaining to the head-gear and a red fillet round the head, which is the Kafir equivalent to the Scotch snood. Both sexes wear ear-rings, neck-rings, and wrist-rings of silver, pewter, or brass. These are left off during mourning. The men first wear them on arriving at manhood, and their first assumption is a matter of festivity and ceremony.

All this chiefly applies to the common people. The wealthier wear a shirt beneath the vest in winter, and in summer a shirt in place of the vest. With the women, the shirt is always the chief garment. Instead, too, of a goat-skin, the rich wear cotton, or black hair-cloth; and sometimes a sort of white blanket of Kashkari manufacture, which is put on like a Highland plaid. Cotton trowsers form another *item* in the more elaborate styles, worked with flowers in red and black worsted, slit at the bottom, and fringed. Worsted stockings, or perhaps woollen fillets, are sometimes worn: as are half-boots of white goatskin by the warriors.

It has been stated that the killing of a Mussulman confers distinction. Until a young Kafir has done this, he misses many privileges. When, however, he has done so, he wears, at the solemn dances at the festival of the *Numminant*, a sort of turban, with a feather stuck into it for every Mussulman that has died by his hand. The number of bells round his waist is similarly regulated; and so is the right of flourishing his axe above his head in the dance. A red woollen cap, or cockade, is another mark. This is worn habitually. Those who have killed many, erect a high pole before their doors, in which are holes. In these are put a pin for every Mussulman killed, and a ring for every one wounded.

All this insures the unfortunate prisoner of the Kafir death rather than slavery. Hence the Kafir slaves—and they are numerous—are of Kafir blood. Their booty is derived from their numerous intertribual wars, and from a considerable amount of private robbery as well. The strong steal from the weak, even within the same community; sometimes to keep the slave for his own use, sometimes to sell him. An individual who loses his relations soon loses his freedom also. On the other hand, domestic slavery is no inordinate burden; and, without being on the full level of the family of the owner, the slave who is retained in the tribe to which he belongs is not ill-used.

A bow, about four feet and a half long, with a leathern string; arrows made of reed, barbed, and sometimes poisoned; a dagger of a peculiar shape, and worn on the right side; a knife, a flint, and a sort of bark used as tinder, constitute the harness of a Kafir. Fire-arms and swords are but just beginning to be used. Surprisals and ambuscades are commoner than open warfare: and of this more takes place by night than by day.

The Kafir of Kafiristan is the mountaineer of the stock, in his most extreme form. His contrast is to be found in the Persian of such towns as Shiraz, Teheran, or Ispahan; also amongst the Tajiks of Bokhara, who are of Persian blood and language, though the dominant population is Turk. Intermediate to these extremes are the Afghans (or *Patans*, whose language is called the *Pushtu*); the Kurds; and the Biluchi of Biluchistan, with whom the mountaineer character changes to that of the occupants of a sandy desert. In Mekran, and along the shore of the Indian ocean, this desert character of the country increases, until the physical conditions become those of Arabia or northern Africa.

Kafiristan lies on the water-system of the Indus; the Biluchi population extends into Sind; Affghanistan lies along the Indian frontier. This suggests that the next group will be—

GROUP V.—THE INDIAN STOCK.—*Organization Referable to Two Types:* In one the skin is dark, the face broad, the features coarse; in the other, the features are regular, the head dolikho-kephalic, the skin brunette rather than black. —*Language:* Modified by foreign admixture; most so in the northern parts of India.—*Area:* India, Ceylon, the Maldive islands, parts of the Monosyllabic frontier, the mountains of the southern part of Beluchistan, *i. e.* the country of the Brahûi.

Every one admits that there are few countries where the effects of some second element of admixture are more visible than they are in India. Few, however, agree as to the exact nature and proportions of this element. It is also admitted that it shows itself nowhere more conspicuously than in the language. In the south, and in the more impracticable mountain ranges, there is no doubt as to its character. In the south, and in the more impracticable mountain ranges, so far as even the Rajmahali hills on the Ganges, the forms of speech all belong to a class called *Tamul*, or *Tamulian*, though spoken with notable differences of dialect, and even language. At the same time there is a vast number of words, even in the purest of them, from another tongue, called the *Sanskrit*. Nevertheless, the Sanskrit admixture is not sufficient to obscure the original Tamulian character of the tongue; *i. e.* it never does so in the southern half of the peninsula at all, and it fails to do so in many of the more impracticable localities towards the north. Even in Persia, amongst the Brahûi of Beluchistan, this Tamul class of language is to be found.

But in the *north* this is not the case. In northern localities, and on level surfaces, like those afforded by the valley of the Ganges, the Sanskrit words are so numerous, and the Tamulian so comparatively few, that the class to which the language belongs becomes doubtful,—the only points which are universally admitted being the fundamental difference between the Sanskrit and Tamul, when we succeed in separating them, and the Indian origin of the Tamul. Whether the Sanskrit be equally Indian, and what it be if other than Indian, are points of doubt.

Under all and any point of view, however, India is the country of two ethnological influences, the analysis of them being a point of minute and recondite criticism—of two ethnological influences; perhaps of more than two. It is the country of castes, of the Brahminic and Bhuddhist religions; of a teeming, ingenious, and industrious, but rarely independent, population. It is the country of an ancient literature, and an ancient architecture. It is a country which, whatever may have been the origin of its own civilization, helped to civilize the majority of the countries of the monosyllabic languages—Ava, Tibet, Siam, and (more than is generally believed) China.

To the Brahminic and Buddhist religions, India stands in the same relation as Arabia does to Mahometanism.

Just as the Kafiristan mountains preserve fragments of the Persian stock in its unmodified form, so do the numerous hill-ranges of India preserve samples of the indigenous Pagan populations, as opposed to those of the Brahminic, Buddhist, and Mahometan creeds. Of these hill-tribes some are almost wholly free from the effects of foreign influence, some considerably modified, some as referable to one class as another. The most usual names by which they are designated, are:—Bhils and Khonds;

the Bhils on the western, the Khonds on the eastern, side of the peninsula. These, along with some denominations of less importance, constitute what is called the *Hill-tribes* of India.

With the Brahminic and Buddhist populations the language gives us the best line of demarcation. In the south the Tamulian character of it is sufficiently clear to be undoubted; whereas in the north the Sanskrit element makes it equivocal.

a. To the former class belong the Tamul (proper), the Telinga, the Kanara, the Tulava, the Malayalam, and the Coorgi forms of speech.

b. To the latter, the Punjabi, the Multani, the Sind, the Gujerati, the Rajputana dialects, the Hindi, the Bengali, and Udiya, with others.

GROUP VI.—THE OCEANIC GROUP.—*Area:* the Peninsula of Malacca, Sumatra, Java, and the chain ending in Timor and Rotti; Borneo, and the chain leading to the Philippines; the Philippines; the Bashi and Babyani Isles; Formosa, Celebes, and the Moluccas; the islands between Timor and New Guinea; Madagascar.

Divisions: Amphinesian and Kelænonesian.

The Pelew Isles, and Lord North's Isle; Micronesia (*i. e.* the Caroline and Marianne Islands).

Polynesia (*i. e.* the Navigator's, Society, Friendly, Marquesan, and Sandwich Island groups); Easter Island, and New Zealand.

The Fiji Islands.

New Guinea, and the islands to the east thereof (*i. e.* Louisiade Archipelago, &c.); Tanna, New Caledonia.

Tasmania (Van Diemen's Land).

Australia.

Language: Agglutinate rather than Monosyllabic. When Amphinesian, with patent and recognised affinities to the Malay; when Kelænonesian, with Malay affinities fewer, more obscure, and only partially recognised.

Physiognomy: When Amphinesian, more brown (or yellow) than black, also more Mongol than Negro. When Kelænonesian, more black than brown (or yellow), and as much Negro as Mongol.

N.B.—The words *nesos = island; amphi = around; kelænos = black (dark); mikros = little; polys = many; protos = first.* They are all Greek. The explanation of their meaning is necessary for the comprehension of the terms used in our classification.

With the Indian group the notice of all the populations of continental Asia ended, with three exceptions. The first was *Arabia*, which is, in respect to its ethnology, African rather than Asiatic. The second was the Namollo population on Behring's Straits, which is Eskimo, and American. The third was the southern extremity of the so-called *Trans-gangetic* or *Indo-European* area, the peninsula of Malacca. *Geographically*, this is a continuation of Siam; *ethnologically*, it is something very different.

Ethnologically, the peninsula of Malacca is *Malay* rather than Siamese; it is also *Oceanic* rather than *Monosyllabic*. It is *Oceanic*, but, with the exception of a small patch of country on the coast of Cambojia, it is the only portion of the vast Oceanic occupancy which belongs to the *continent of Asia, and not to the islands of the Indian Archipelago and the Pacific Ocean.* This explains the meaning of the term. Nine hundred and ninety-nine parts of the population before us are islanders. Their diffusion is one of the most extraordinary phenomena in ethnology. Madagascar is Oceanic rather than African, though so far from Malacca, and so near the Mozambique coast; and Easter Island, isolated as it is, is Oceanic also. The Sandwich Islands are Oceanic, and New Zealand is Oceanic also.

MALAY.

The Protonesian Branch of the Amphinesians.—By Amphinesian I mean that division of the Oceanic population which, from being found in New Zealand, in the Society Isles, and in the Moluccas, may be said to *surround* the Kelænonesians, who are limited to Tasmania, Australia, New Guinea, and the islands between New Guinea and New Caledonia (*amphi* = *around; nesos* = *island*).

By Protonesian I mean that part of Amphinesia which lies nearest the continent, and from which the Oceanic diffusion *first* took its rise (*protos* = *first*). It includes, along with the Malaccan peninsula, the islands of the Javanese, Celebes, Floris, Banda, Molucca, and Philippine archipelagos, viz., Sumatra, Java, Borneo, &c., &c. It begins with the parts about Sumatra and the Malaccan peninsula, and ends with the Philippines. I imagine that from the western part of Protonesia a few individuals found their way to Madagascar, and gave origin to the Malegasi division; that from the north-eastern parts (*i. e.* the parts about the Philippines) Micronesia was peopled, *via* the Pelew Isles, Lord North's Isle, &c.; that from the southern parts (*i. e.* the Isles of Timor and Rotti) Australia took its population; and, finally, that from the parts, at one and the same time, eastern and central (such as the Arru Isles), New Guinea was peopled.

Such I hold to be the offsets from Protonesia. But this not all. The population of Protonesia is varied. In the towns on the sea-coast, and in the commercial localities, the religion is Mahometan—the greater part of the population being known by the name *Malay*. With these the industry is commercial and maritime. But before the spread of the Mahometans there were Indian influences at work. Fragments only of these can now be found; except in the single Isle of Bali, which is Hindu in creed and literature at the present moment. Earlier than these Hindu influences is the original Paganism. This also is found in fragments only, or (if not in fragments) in a modified form, due to influences from India and Arabia. Borneo is its chief seat.

PHILIPPINE ISLANDER.

Now these ruder and more unmodified populations of Protonesia fall into two divisions in respect to their physical appearance. There is a division of them no darker than the ordinary Malays, and there is a division which is so far *black* as to take the same place amongst the Oceanic tribes as the Mincopie did amongst the Monosyllabic.

From this black variety I imagine that the Kelænonesian Islands were peopled; *i. e.* New Guinea from the Arrus (there, or thereabouts); Australia from Timor.

More than this, the Protonesian Blacks are peculiar in their distribution. They are not limited to one or more islands; whilst it is rarely that they form the exclusive populations of those whereon they are found. On the contrary, they are found in *most* of the islands, and chiefly among the lighter variety. *But they are always found in the interior or more impracticable parts, and always as an inferior population.* From this we infer that they are the older occupants. Also, that the migration to Kelænonesia took place anterior to the spread of the lighter tribes; *i. e.* when Protonesia was *wholly* what it now is partially—Kelænonesian.

POLYNESIANS.

On the other hand,

Micronesia was peopled from the north-eastern parts of Protonesia, after the lighter population had diffused itself, *i. e. later*. Colour and language indicate thus much. And

Polynesia was peopled from Micronesia; the stream of population thus being taken *round* Kelænonesia.

Polynesia and Micronesia represent *Eastern* (or North-eastern) Protonesia, as extended in the direction of America. *Western* Protonesia, as extended in the direction of Africa, is represented by

The Malegasi of Madagascar.—That the language, at least, of Madagascar is Malay rather than African, is one of the most remarkable facts in Ethnology. Yet the presence of an allied population in Easter Island is equally so. This gives importance to the physical history of the *ocean*—to the study of its currents and winds, which is brought to completion by maritime enterprise on the part of the populations that occupy it. Hence facts like the following want accumulating:—

a. Captain Beechy informs us that he picked up, at sea, a tempest-driven canoe, belonging to Chain Island, three hundred miles east of Tahiti, and subject to it. She had been on a voyage to the latter, and by two successive gales from the westward was driven six hundred miles out of her course, to Barrow Island, in about the twentieth degree of south latitude. When rescued, she had on board twenty-eight men, fifteen women, and ten children; in fact, the nucleus of a little colony.

b. Again: Captain Wilson found, when wrecked on the Pelew Islands, in 8° of north latitude, and 135° of east longitude, three Malay mariners; and, having among his own crew a Malay interpreter, he was able to communicate with the natives through these Malays, who had acquired the Pelew language. The account which they gave of themselves was, that in a voyage from Batavia to Ternate, one of the Moluccas, touching at Menado in Celebes, they were driven by a storm on the Pelew Islands.*

c. Again: a Japanese junk is known to have drifted to the coast of California.

Such, and such like, are the chief facts required for the comprehension of the remarkable distribution of the more distant oceanic tribes.

The Papuans of New Guinea, New Ireland, New Hebrides, &c., are **Kelænonesians,** with frizzled hair—strongly frizzled; far more frizzled than is the case with

The Australians, the second division of the Kelænonesians.

The third division of the Kelænonesians is that of

The Tasmanians of Van Diemen's Land, nearly extinct, and, as such, claiming further notice.

NEW ZEALANDER.

It is in Tasmania that domestic architecture appears in its very humblest form; yet this is only what we expect from the low civilization of the natives, and the character of the climate. In the mountainous parts of the country the chief retreats were the caves and hollows of the districts, of which there is an abundance; so that it is only in the more exposed plateaux that even so much as a break-wind is needed. This consists of the branches of trees firmly wedged together, and supported by means of stakes. Crescentic in form, its convex side is opposed to the wind. A fire is kept burning in the uninclosed space, to the leeward. Half a wall, and no roof—such is the shelter of the Tasmanian.

Grass baskets, waddies (or spears), a large shell for carrying water, some smaller ones for the purposes of personal decoration, are the chief articles of the furniture of the Tasmanian. More essential, however, than any of these were the means for kindling their fires. The author to whom the present details are more particularly due, most expressly states that their memory supplies them with no instance of a period when they were obliged to draw upon their invention or ingenuity for the artificial production of a fresh flame; so that the North American practice of rubbing two pieces of wood together, and getting a fire through friction, is unknown. Hence the importance of a perpetual fire is so keenly felt, that it is never allowed to die utterly away. Neither does any migration take place without the females making it their especial duty to look to the firebrand, and to keep alight its fire. It is the female's duty, too, to carry it about.

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* Mr. Craufurd, in "Transactions of Ethnological Society."

Their movements on the water—limited, of course, to the tribes on the coast—seem to have been effected by catamarans rather than by true canoes; and the planks of these were fastened together by means of rush bands, or else skin thongs. The search after wild animals and the natural productions of the soil was their business—the dance their relaxation.

These small migratory bands recognised the imperfect leadership of the individuals who had the greatest force of character; in other words, they had no hereditary, no regularly elective, chieftaincies. Another negative characteristic was the absence of all such influences as originate out of the pretension to divination, theurgy, or witchcraft. In sickness the patient was relieved or tormented, as the case might be, by non-professional advisers, and the application of an ordinary chirurgery. He was bled, for instance, with a flint, or a crystal sharpened for the occasion; and the friend who bled him was the first that had the opportunity of doing so. No one presumed to be specially qualified for such offices. The women watched over the dying, and the dead were usually burned.

An imaginary spirit, disposed to hurt and annoy them, and more especially so disposed during the night, was the chief element of their mythology. There was also the belief of a world beyond the grave, wherein game was to be abundant, and the chase successful. More specific, however, than these common and universal elements of superstition are the following two customs, which still retain their ground. The one is the anxiety to possess a bone from either the skull or the arm of their deceased relatives, to be sewn up in a piece of skin, to be worn round their necks, and to act as an amulet against sickness or premature death. The other is the fear of pronouncing the name of a deceased friend.*

This is Australian and Polynesian also.

The Tasmanians have generally been described as samples of the lowest form of humanity, and that perhaps rightly. The details as to the trouble they take about keeping up a source of fire are important; inasmuch as the difficulty they have in doing so has led to the statement that they alone of all human populations were, when discovered, ignorant of it.

In the Fiji Islands, the parts of Polynesia nearest to Kelænonesia, the colour points one way, the language another—the one towards the Society Isles, &c., the unequivocally Polynesian populations; the other towards the Papuan Islands. Were these Kelænonesian in the first instance?

The following description is from the American Exploring Expedition:—

"The Feejeeans are a people of the medium stature, with nearly as great variety of figure as is found in nations of the *Caucasian* race. The chiefs are usually tall and well formed, owing probably to the care taken of their nurture, and to the influence of blood. The common people are somewhat inferior; yet there are fewer small and ungainly figures among them than among the lower orders of Europeans. On the other hand, the *Feejeeans* contrast very unfavourably with their neighbours of the *Polynesian* stock. They lack the full rounded limbs and swelling muscles which give such elegance to the forms of the Friendly and Navigator's Islanders. They are generally large-jointed, and the calf is small in proportion to the thigh. The neck is also too short for due proportion, and the whole figure wants elegance and softness of outline. Their movements and attitudes are, consequently, less easy and graceful than those of the *Polynesians*. They are, nevertheless, a strong race; their war-clubs are ponderous, and are wielded with great power, and they can carry very heavy burdens.

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* "Moral and Social Characteristics of the Aborigines of Tasmania, as gathered from intercourse with the surviving remnant of them, now located in Flinders Island." By the Rev. T. Dove, late of Flinders Island.—*Tasmanian Journal of Natural Science, &c.* Vol. I.

"The *Feejeean* physiognomy differs from that of the *Polynesians*, not so much in any particular feature as in a general debasement of the whole, and a decided approximation towards the forms characteristic of the Negro race. The head is usually broad in the occipital region (which they consider a great beauty), and narrows towards the top and in front,—the forehead, though often of good height, appearing compressed at the sides. The eyes are black and set rather deep, but never obliquely. The nose is not large, and is generally a good deal flattened; the nostrils are often larger laterally than forwards, and the nose is then much depressed at the upper part between the eyes. The mouth is wide, and the lips, particularly the upper one, thick. The chin varies, but is most commonly short and broad. The jaws are larger, and the lower part of the face far more prominent than in the *Malay* race. The cheek-bones, also, project forwards as in the Negro, and not laterally, as in the *Mongol* variety; notwithstanding which, the narrowness of the forehead at the temples gives a greater width to the face at the malar portion than elsewhere. The whole face is longer and thinner than among the *Polynesians*. The hair is neither straight nor woolly, but may be properly designated as frizzled. When allowed to grow without interference, it appears in numerous spiral locks, eight or ten inches in length, spreading out on all sides of the head. Sometimes these curls are seen much longer, falling down to the middle of the back. It is, however, very seldom allowed to grow naturally. The young boys have it cut very close, and sometimes shave to the skin, like the *Tahitians*. In girls, before marriage, it is allowed to grow long, and is coloured white by washing it with a solution of lime, except a portion around the crown, which is plastered with a black pigment. After marriage, it is either cut to the length of one or two inches, or frizzled out like that of the men: in both cases it is frequently soaked in colouring liquids, either red or black. The men in general have their hair dressed so as to form an immense semi-globular mass, covering the top, back, and sides of the head. The arrangement of this chevelure is performed for the chiefs by professional barbers, and is a work of great labour. Six hours are sometimes occupied in dressing a head; and the process is repeated at intervals of two or three weeks. It is probably to guard against disarranging this work that the piece of bamboo which is placed under the neck in sleeping is employed, instead of the ordinary pillow. For the same purpose the natives usually wear, during the day, a *sala* or *kerchief*, of very thin gauze-like paper cloth, which is thrown over the hair, and tied closely around the head, so as to have very much the appearance of a turban.

"The colour of the *Feejeeans* is a chocolate-brown, or a hue mid-way between the jet-black of the Negro and the brownish-yellow of the *Polynesian*. There are, however, two shades very distinctly marked, like the blonde and brunette complexions in the white race; besides all the intermediate gradations. In one of these shades the brown predominates, and in the other the copper. They do not belong to distinct castes or classes, but are found indiscriminately among all ranks and in all tribes. The natives are aware of the distinction, and call the lighter-coloured people *Viti Ndamundamu*, 'red *Feejeeans*;' but they do not seem to regard it as anything which requires or admits of explanation. These red-skinned natives must not be confounded with the *Tonga-Viti*, or individuals of mixed *Tongan* and *Feejeean* blood, of whom there are many in some parts of the group."

The real difficulties of the Oceanic class lie in the apparently abrupt lines of demarcation which separate the primary divisions, especially the Kelænonesian from the Amphinesian; indeed it is only by concentrating our attention on the black varieties of the Protonesian area, and by remembering the likelihood of their once having formed the preponderating population, that we can see our way to the connection. And even when this has been done, the difference between the Kelænonesians themselves is remarkable. Let us notice some of the blacks of this same Protonesia.

They have not been found in Borneo—at least they have not been found so as to be definitely described; nor yet in Sumatra. In the peninsula of Malacca, however, they *have*. They have been found, and they have been examined—the name by which they are denoted being Semang. Let us look at the colour of the Semang skin. The complexion is dark; the hair curly and matted, but not frizzled. This is what Mr. Newbold relates; premising that he had no opportunity of personally judging. Mr. Anderson and Sir S. Raffles describe this darkness of complexion in stronger terms.

The Semang of Quedah has the woolly hair, protuberant belly, thick lips, black skin, flat nose, and receding forehead of the Papuan.

The Semang of Perak is somewhat less rude, and speaks a different dialect.

More than one Malay informed Mr. Newbold that the Semangs were essentially the same as the Jokongs; having the same hair, but a somewhat blacker skin.

They live in rude moveable huts, constructed of leaves and branches, scantily clothed, and fed from the produce of the chase, at which they are expert. Their government is that of chiefs or elders. The Malays accuse them of only interring the head, and of eating the rest of the body, in cases of death.

Here, then, is one of the populations coming under the category indicated, being dark in skin, impracticable in locality, rude in manners. Yet the Malay who compared them with the Jokong suggested the unlikelihood of the distinction between the Semang and the other populations being very decided; inasmuch as the Jokongs are Semang in everything but colour, *whilst both Semang and Jokong are Malay in language*.

Now let us take the islands that lie east of Java, and, of these, the eastern end. In Timor the skin darkens, the lips thicken, and the hair gets frizzly. In Ombay the population is described by Arago as being black cannibals, with flattened noses, and thickened lips.

Then as to their speech. Marsden calls the languages of the Semang, and the darker tribes of Polynesia, *Negrito;* and having done so, remarks, "We have rarely met with any Negrito language in which many corrupt Polynesian words might not be detected. In those of New Holland or Australia such a mixture is not found. Among them no foreign terms that connect them with the languages, even of other *Papua* or Negrito countries, can be discovered. With regard to the physical qualities of the natives, it is nearly superfluous to state, that they are Negritos of the most decided class."

This is important, if accurate; but it is not so. The Ombay, and two other dialects, the Mangarei and Timbora, are known to us by scanty vocabularies of some two dozen words; yet these give us the following affinities with the Australian dialects:—

1. Arm = *ibarana*, Ombay; *porene*, Pine Gorine dialect of Australia.

2. Hand = *ouine*, Ombay; *hingue*, New Caledonia.

3. Nose = *imouni*, Ombay; *maninya*, *mandeg*, *mandeinne*, New Caledonia; *mena*, Van Diemen's Land, western dialect; *mini*, Mangerei; *meoun*, *maidge*, *mugui*, Macquarie Harbour.

4. Head = *imocila*, Ombay; *moos* (= hair), Darnley Island; *moochi* (= hair), Massied; *immoos* (= beard), Darnley Islands; *eeta moochi* (= beard), Massied.

5. Knee = *icici-bouka*, Ombay; *bowka*, *boulkay* (= fore-finger), Darnley Islands.

6. Leg = *iraka*, Ombay; *horag-nata*, Jhongworong dialect of the Australian.

7. Bosom = *ami*, Ombay; *naem*, Darnley Island.

8. Thigh = *itena*, Ombay; *tinna-mook* (= foot), Wioutro dialect of the Australian. The root, *tin*, is very general throughout Australia in the sense of *foot*.

9. Belly = *te-kap-ana*, Ombay; *coopoi* (= navel), Darnley Island.

10. Stars = *ipi-berre*, Mangarei; *bering*, *birrong*, Sydney.

11. Hand = *tanaraga*, Mangarei; *taintu*, Timbora; *tamira*, Sydney.

12. Head = *jahé*, Mangarei; *chow*, King George's Sound.

13. Stars = *kingkong*, Timbora; *chindy*, King George's Sound, Australia.

14. Moon = *mang'ong*, Timbora; *meuc*, King George's Sound.

15. Sun = *ingkong*, Timbora; *coing*, Sydney.

16. Blood = *kero*, Timbora; *gnoorong*, Cowagary dialect of Australia.

17. Head = *kokore*, Timbora; *gogorrah*, Cowagary.

18. Fish = *appi*, Mangarei; *wapi*, Darnley Island.

Now let us look at the Arru Isles, about sixty miles from New Guinea, extending over a space of about one hundred miles in length, and forty-five in breadth. They are nearer New Guinea than they are to any of the larger isles westwards. There is no doubt as to the difference between the natives of this group and the Malays, or Moluccans. The colour of the skin has changed from brown to black, and the stature has increased. The height of the men sometimes approaches six feet; but we may say that the usual range is from five feet four to five feet eight. The chests are broad, but the lower extremities thin off, and become disproportionately slim. The most palpable fact, however, connected with the Arru organization, is one mentioned by Mr. Earl, viz., that when some of the aborigines of Port Essington were landed on the islands from an English ship, the natives mistook them for the inhabitants of some of the more distant parts of their own archipelago. The hair is strongly curled, and harsh, the use of alkaline washes being general.

When an Arru islander dies, no one of his surviving relations thinks it right to use any articles of property he may have left behind—no pot or basin, no weapon, no musical instrument. The owner is no more, and his relics must cease to be put in use. So they are all broken to pieces, or thrown away. Then the body is laid on a mat, and rested against a ladder, until the mourners meet. As decomposition proceeds, attempts are made to arrest it by the application of lime. Meanwhile, resins are burnt in the house, and the guests hold a wake—drinking, howling, and beating gongs. Food, too, is offered to the corpse—crammed, indeed, into the mouth, until it runs down and spreads over the floor. Dishes of china are set to catch any moisture from the body; the value of the dishes being enhanced by the office they have served.*

When a young man will marry, he purchases his wife of her parents; but the payment is made by instalments, spread over several years. When unpossessed of property, the bridegroom elect travels amongst his friends to collect, taking island after island, and often making an expedition of a whole year. In this way he levies contributions of elephants' teeth, porcelain, cloth, and gongs. He returns, he is feasted, and becomes betrothed.

To enter another man's house during his absence is a misdemeanour, for which a piece of cloth, or some other article, is paid as a fine. To touch another man's wife is an offence still more heinous, for which the fine is proportionately heavier.

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* Lieutenant Kolf's "Voyage of the Durga," translated by G. W. Earl.

The purest and most unmixed of the Arru populations are the occupants of eastern islands; in the north-western parts they become mixed. There it is where the trade is most active, and there it is where the Chinese, Javanese, Bugis, and Europeans resort for barter. Pearl oysters, edible birds' nests, and trepangs are the chief exports. These the Arru collect with industry, for they are an active, thriving population, with strong industrial and commercial propensities; not surly and uncivil to strangers, but, on the contrary, well-disposed and open-tempered,—addicted to piracy in some localities, to honest trade in others.

Black and barbarous as much of the Arru population is, their language connects them with the Malays and other Protonesians, as truly as their form connects them with the Papuans.

I am making out a case for connecting the Kelænonesians with the Amphinesians; but I refrain from stating any opinion as to the value of the two groups, as well any opinion as to the value of any of their subdivisions. I also admit the great amount of physical and philological difference; but admitting this, I also suggest to the reader the careful consideration of the great difference in the physical conditions of areas like New Guinea and Australia, and areas like the islands of the Indian Archipelago and South Sea. I also remind him that whatever may be the length of time, during which Micronesia and Polynesia have been separated from Protonesia, the Kelænonesian isolation is of earlier date still.

Another fact, too, requires noticing; viz., that Protonesia is not the only part of Amphinesia where the population has skins of two tints. The same occurs in Micronesia—the same in Polynesia. Sometimes the difference coincides with a difference of caste—sometimes with a difference of locality. Sometimes different islands of the same Archipelago are differently characterized. Captain Beechy's remark on this distribution of this blacker variety is important. He finds that it has a special relation to the geological structure of the area; *i. e.* that the lower and coralline islands contain the darker, the higher and volcanic islands the lighter, tribes.

Other instances of a similar relation of the colour of the population occupant to the physical conditions of the parts occupied, will be found when we come to Africa.

At present we must return to the Turanians, and take them up at the north-eastern extremity of Asia; the divisions of them that are of special importance being the Ugrian and the Peninsular. These it is which lead us to

GROUP VII.—THE AMERICANS.—*Area:* The Aleutian Isles; North and South America—remarkable for the comparative absence of domestic animals. *Physiognomy:* Modified Mongol; the departure from the type being the most marked on the water-system of the Mississippi and the coast of the Atlantic. *Languages:* Agglutinate.

The present writer confesses to no such misgivings as to the origin and affinities of the great American group as find place in most works on the subject. He neither finds difficulty in connecting them with the Old World, nor doubts as to the part thereof from which they came. This he finds in north-eastern Asia, just what the *à priori* probabilities of the geographical relations of the two continents indicate.

His reasons for thus making short work of a hitherto long question, lie in the recent additions to our geographical and ethnological knowledge for the parts to the west of the Rocky Mountains—for the northern parts more especially; for Russian America;

for New Caledonia; and for the Oregon. It is only lately that we have known much of these districts, especially in respect to their ethnology. More than this—it is only recently that the *Far West* of the parts between the Rocky Mountains and Atlantic has been at all carefully explored. What followed from this want of information? It followed, as a matter of course, that our notions of the so-called Red Man of America were formed upon the Indians of the Alleghany Mountains, the Mississippi, and the St. Lawrence. But these were extreme samples—samples of the American in his state of greatest contrast to the Asiatic. No wonder, then, that the connection between them was mysterious and uncertain. If investigators doubted, the want of *data* justified them. The populations which were the likeliest to supply the phenomena of transition were unknown or neglected.

Again: there was only one population common to the Old and New World. This was the Eskimo, a population which at one and the same time occupies the Aleutian Islands, the peninsula of Aliaska, the Island of Kadiak, the greater part of Russian America, the coast of the Arctic Sea, Greenland, and Labrador. Here it comes in contact with the so-called Red Indian of the Algonkin class.

Now, between this so-called Red Indian of the Algonkin class, and the Eskimo in geographical contact with him, there is a broad line of demarcation—a line of demarcation so broad as to suggest the idea of contrast rather than connection. Hence, as long as we studied America on its eastern or Atlantic side, we got nothing from the Eskimo; nothing from the fact (apparently so important) of his being common to the two hemispheres, and (as such) being likely to supply the connecting link between them. He was anything but such a link. He was rather a knife to separate than a band to bind. Yet, on the *western or Pacific* side of the continent, this same Eskimo so graduates into the American Proper, and the Indian Proper so graduates into the Eskimo, as to make the distinction between the two groups as difficult as, on the east, it had been easy. Why is this? On the east the Algonkins, a conquering and intrusive population, have spread themselves northwards, and have effaced such transitional populations as may, originally, have existed between them and the Eskimo; whereas, on the west, the conquests, intrusions, and displacements have been inconsiderable. The same phenomenon repeats itself elsewhere—nowhere more clearly than in the northern parts of Europe. The Norwegian and the Laplander are strongly contrasted—very strongly. But this contrast disappears as we go eastwards. The Lap graduates into the Finlander; the Finlander can be thrown in the same group with the Lithuanian and Slavonian; the Lithuanian and Slavonian in the same group with the Scandinavian.

Other phenomena, connected with the distribution and displacement of population which we have observed in Asia, will re-appear in America—*e.g.*, the juxtaposition of large and small ethnological and philological areas. In Asia we found, on one side, the Turk tribes, spread over a space nearly as large as Europe, and that with but little variation—a typical instance of what constitutes a large ethnological area. Then, on the other hand, were the fastnesses of Caucasus, where we found, packed up within a very limited area, a multiplicity of mutually unintelligible languages,—languages that were counted by the dozen and the score—the Circassian, Georgian, Leagian, Mizjeji, and their subordinate dialects. So that within a small geographical range we had, in juxtaposition with each other, the *maximum* of extension and the *maximum* of limitation.

Now this is what we shall find in America.

The larger groups will be noticed first—those of North America taking the precedence.

The Eskimo.—The Eskimo are eminently a maritime family: maritime whether they occupy islands like the Aleutian Archipelago, peninsulas like that of Aliaska, or broken lines of coast like those that form the shore of the Arctic Sea. Even in Russian America, Greenland, and Labrador, large blocks of land as they are, it is only along the coast that the Eskimo is distributed.

The Eskimo is *one* of the populations of North America that stretch all across the continent, from west to east, from the Atlantic to the Pacific. Common to two continents, the Eskimo area is also common to two oceans. The *other* population that does so is—

The Athabaskan.—The Eskimo, in his stretch across the continent, reaches the open expanse of the Atlantic on the eastern coast of Labrador. The Athabaskan extends only to the great inlet of Hudson's Bay. He underlies the Eskimo, so to say. At Cook's Inlet, in 60° N. Lat., he appears on the Pacific; to the north of Port Nelson on the Atlantic—*i. e.* on Hudson's Bay. As a general rule, the southern limit of the Eskimo is the northern limit of the Athabaskan: the extension being, in both cases, from east to west (or *vice versâ*); being *horizontal*.

The Athabaskans, however, extend from north to south, as well as from east to west, and, what is more remarkable, they have given off offsets. Just as the Majiars of Hungary belong to the essentially northern stock of the Ugrians, from which, however, they are geographically separated by a wide interspace, so do certain tribes of Mexico and California—tribes on the very verge of the Tropics—belong to those very Athabaskans whose true area is the inland parts of Russian America, the northern range of the Rocky Mountains, the valley of the Mackenzie river, the parts about the Great Slave Lake, and the parts about Lake Athabaska—whence the name. Some of them lie within the Arctic Circle.

The general distribution of the Athabaskans is more important than the details. The chief tribes, however, are—the Chipewyans (or Northern Indians, so called); the Beaver Indians; the Daho-dinni; the Strong-bows; the Hare Indians; the Dog-ribs; the Yellow-knives; the Takulli (or Carriers); the Tsikanni; the Sussi; the Loucheux; and the Kenay of Cook's Inlet, along with other minor tribes.

To these we must add the outlying sections of *a*, Oregon, *b*, California, *c*, Mexico.

a. In Oregon the Athabaskans consist of three small tribes, of which the first two, the Kwaliokwa and the Tlatskanai, consisting each of about one hundred individuals, lie at the mouth of the Columbia river—one north, the other south of it. The third tribe, that of the Umkwa, lying on the river so called, numbers about four hundred. This is in 43° N. Lat.

b. In California the Navahos and Jecorillas, wild tribes of the desert, are shown by their language to be Athabaskan, as are some other smaller Californian tribes.

c. In Mexico some of the Apatches are Athabaskan; so far south have Athabaskan offsets been found.

The extent to which the tribual organization prevails may be seen from the following list of names:—

1. The *Taūtin*, or *Talkótin*; 2. the *Tsilkótin*, or *Chiltokin*; 3. the *Naskótin*; 4. the *Thetliótin*; 5. the *Tsatsnótin*; 6. the *Nuladutin*; 7. the *Ntshadutin*; 8. the *Natliáutin*; 9. the *Nikozlidutin*; 10. the *Tatshidutin*; and 11. the *Babine* Indians.

These are the *sub*-divisions of a single Athabaskan division, the Takulli of New Caledonia,—an example of which forms the Frontispiece of the present volume.

The Algonkins.—The great Algonkin class extends but little to the west of the

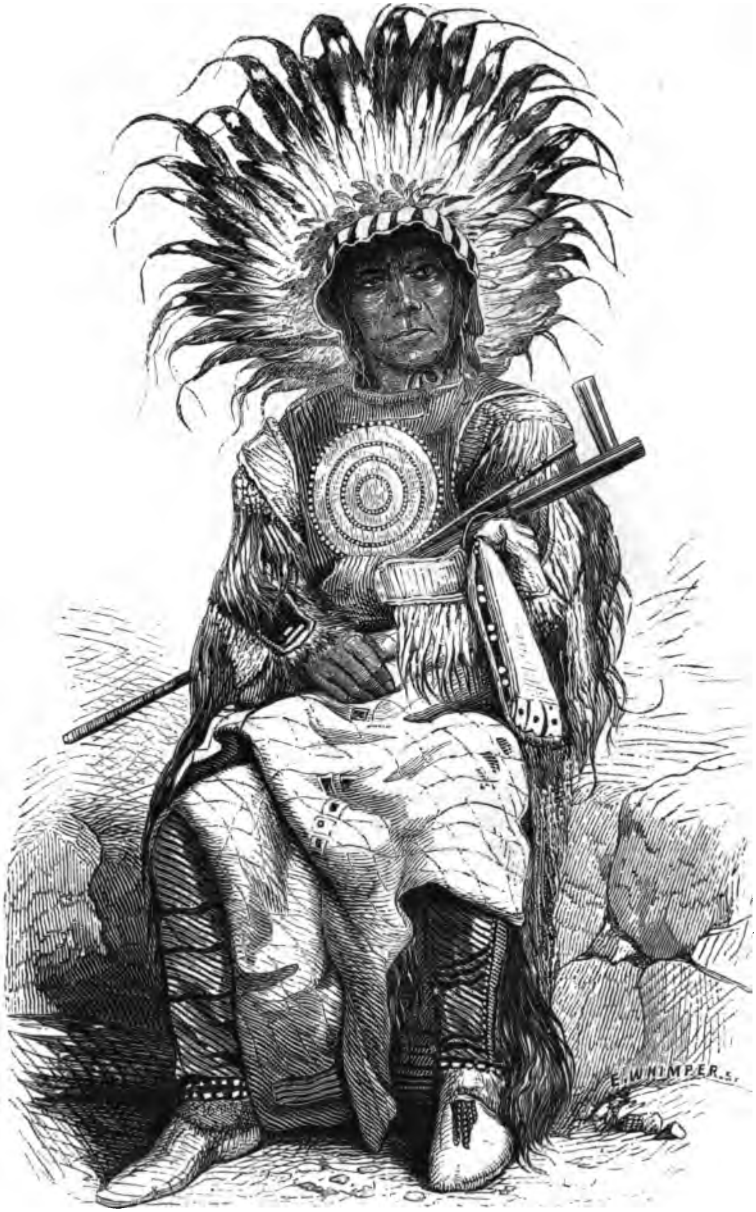
Rocky Mountains; so that its east-and-west or horizontal direction is smaller than that of the Eskimo. Nevertheless it is the largest of all the North American groups.

A SAC CHIEF (ALGONKIN).

It subtends both the Athabaskan and the Eskimo areas,—the former from the Rocky Mountains to Hudson's Bay, the latter in the southern and central parts of Labrador. Here the country of the Skoffi (or Nascopi) and Sheshatapush reaches 60° N. Lat. On the south, the parts about Cape Fear, and in South Carolina (34° N. Lat.), is Algonkin; the occupancy of the now extinct tribe of the Pamtico.

The vast area of the Algonkins surrounds and incloses that of

The Iroquois suggesting the idea of encroachment, conquest, and displacement. If the Iroquois family cover less ground than the Algonkin, its historical prominence is equal, or even greater. The famous confederacy of the Five Nations was Iroquois. The once formidable Mohawks were Iroquois. Before the arrival of the Europeans the Five Nations were dominant over their Algonkin neighbours; and after the arrival of



TAKULLI CHIEF (*referred to at page* 351).

the Europeans the Iroquois warriors were more feared than those of the Algonkins. At one time the head of the Algonkin confederacy was an Iroquois chieftain.

The Iroquois and Algonkins exhibit, in the most typical form, the characteristics of the North American Indians, as found in the earliest descriptions; and they are the two families upon which the current notions respecting the physiognomy, habits, and moral and intellectual powers of the so-called Red Race are chiefly founded.

DELAWARE AND BLACKFOOT ALGONKINS—MOHAWK IROQUOIS.

As a general rule, though not without important exceptions, the Algonkin and Iroquois classes lie to the east of the Mississippi, and their original area was the region of the forest rather than the prairie. The region of the prairie rather than the forest, is the occupancy of

The Sioux.—The valley of the Missouri is Sioux; the foot of the Rocky Mountains is Sioux; the Red River is (northern) Sioux; the Arkansas is (southern) Sioux; the greater part of the buffalo country is Sioux.

A SEMINOLE YOUTH (*Creek class*).

So much has to be done, in respect to the classification of the American tribes, that the value of the foregoing groups is anything but uniform. The Sioux and Iroquois, for instance, should probably be subordinated to some higher denomination; and this higher denomination should probably contain the following sections:—

The Woccons and Catawbas of Carolina;

The Cherokees, Choctas, and Creeks of Tenessee, South Carolina, Mississippi, Louisiana, Florida, Alabama, and Georgia;

The Caddo of Texas.

Of these the Cherokee is one of the few so-called savage nations which is increasing, and not decreasing, in numbers. It is also the most industrial of all the American families; the Cherokee landholder having, in some cases, as much as five hundred acres under tillage, and possessing slaves as well. Lastly, a native Cherokee has reduced the language to writing — the alphabet being syllabic.

The Paducas.—The form of the area occupied by the Paduca class is remarkable. It extends *nearly* from sea to sea, like the Athabaskan and Eskimo, but its direction is *oblique*. In the Oregon territory, and on the middle Columbia, populations called the Wihinast and Shoshoni approach the Pacific. In Mexico and Texas, and on the Rio Grande, a population called the Cumanch approaches the Gulf of Mexico; the Cumanch, the Shoshoni, and the Wihinast being equally Paduca. Other members of the class, spread eastwards, in the direction of the Platte and Arkansas rivers, westwards into the Californian desert.

Such are the larger groups, the size of whose areas remind us of those of the Turks, Mongolians, Ugrians, &c.—the rule being, a large area with a comparatively uniform population. We must expect, however, instances of the converse phenomenon as well, viz., the analogues of the Dioscurian distribution.

For the populations now about to be noticed, the areas will be either moderate or small, the differences within them being considerable.

The change sets in as we approach the Mississippi, when differences begin to increase, and distinctions to broaden. The Uché, the Coosadas, the Alibamas, the Taenzas, the Pascagoulas, the Colapissas, the Biluxi, the Chetimachas, the Humas, the Tunicas, the Pacanas, the Natchitoches, the Adahi, the Opelusas, the Attacapas, take us from Florida to Texas—the bulk of the Texian aborigines belonging to the Caddo group. Most, if not all of these, appear to differ as much from each other as any of the more distant members of (say) the whole Sioux, or Algonkin class. It should be added, however, that our information concerning them is very imperfect. Of these the Natchez require further notice, inasmuch as their customs remind us of those of the Mexicans. They practised human sacrifices on the death of their chief. They not only worshipped the sun, but (like the ancient Romans) kept burning an eternal fire. Their religion so far acted upon their social or political constitution, as to develop a sort of caste-system, the principal chief being the Great Sun, and his children, Suns; whilst the portion of the tribe, not supposed to be so descended, were destitute of civil power. Their nobility was transmitted through the female.

The Attacapas, too, demand notice. Judging from a specimen of their language, it is one of the tongues of America whereof the original monosyllabic character has yet to become agglutinate.

Further north, amongst or in contact with the Sioux, the Riccarees, Pawnees, and Ahnenin have yet to be classified.

But the multiplicity of small or moderate populations attains its *maximum* in the parts between the Rocky Mountains and the Pacific. Proceeding from north to south,

The Koluch come first. In the parts about Sitka, or New Archangel, the Koluch characteristics are pretty definite. As soon, however, as we move northwards and eastwards, the lines of demarcation between them, the Athabaskans and the Eskimo grow indistinct. For these parts, and the parts south of them, the coast-line is broken, the islands numerous, and the populations maritime in their habits.

The Haidah occupy Queen Charlotte's Islands, &c.—

The Chemmesyan; Observatory Inlet, and the parts about 55° N. Lat.—

The Billechula; the mouth of Salmon River, 54° N. Lat.—

The Hailtsa; the coast as far as Vancouver's Island.—

The Nútkans; Vancouver's Island.—

In the interior, and on the water-system of Frazer's River, lies a family of considerable dimensions, falling into divisions and subdivisions, viz., the *Tsihaili* (*Atna*, or *Shushwap*).

At the back of the Atnas and on the Rocky Mountains are the Kitunaha, or Flatbows. These touch the Blackfoots on the east—the Blackfoots being Algonkin.

The Chinuks are on the mouth of the Columbia, a population falling into divisions and subdivisions; a population of which the physical appearance, as described by Pickering in the United States Exploring Expedition, is as follows:—"The personal appearance of the Chinook differs so much from that of the aboriginal tribes of the United States, that it was difficult at first to recognise the affinity. Taking them collectively, they are even inferior in stature to the tribes of Interior Oregon; the general form is shorter and more squat, and the face is rounder and broader when viewed in front. Instances occurred of a fairness of complexion, which I have not seen in other parts of aboriginal America; and in young children the colour was often not strikingly deeper than among Europeans. The oblique eye I have scarcely noticed in other parts of America; nor such frequent difficulty in distinguishing men from women, whether in youth or age. The arched nose was, however, very prevalent among the Chinooks. The beard was not always absolutely wanting, but it occasionally attained the length of an inch or more. One man had both beard and whiskers, quite thin, but full two inches long; and in other respects he much resembled some representations I have seen of the Esquimaux. . . . The head is artificially flattened in infancy; but as the children grow up, the cranium tends to resume its natural shape, so that the majority of grown persons hardly manifest the existence of the practice. One effect, however, seemed to be permanently distinguishable in the unusual breadth of the face." This flattening of the head appears and re-appears in several parts of America; the parts on the Lower Columbia supplying numerous instances amongst the Chinuk populations, and amongst populations other than Chinuk. Higher up on the Columbia comes another family—

The Sahaptin—the first of the Oregon tribes for industry and docility; rare characteristics amongst the inland tribes of America, though not amongst the maritime.

Divisions and differences still continue; indeed the details of the ethnology of South Oregon and California consist chiefly in the names of obscure tribes, speaking mutually unintelligible tongues—Yakon, Kalapuya, Lutuami, Saintskla, Shasti, Palaik, &c. &c.

The valleys of the Gila, Colorado, and the upper part of the Rio Grande, give us, in the Moqui tribes, and the so-called Indians of the Pueblas, an approach to the industrial condition of ancient Mexico—viz. an incipient agriculture, and a masonry of stone.

The Pima tribes, on the frontier of Sonora, are also (for Americans) industrial. So are (or have been) several other tribes of Sonora, Cinaloa, New Biscay—others being rude and wild.

In Mexico the civilization attains its *maximum;* in Mexico, Central America, and Yucatan. But it is a civilization which has gone by—found only in the ruins of great buildings, and in the accounts of historians.

At present the Central Americans, when occupants of the isolated mountain-ranges, are rude and wild, preserving, in some cases, an imperfect independence. The Lacondona Indians, between St. Salvador and Honduras, are the best samples of this class. The tribes of the Moskito coast give us the other extreme, viz., the effects of intermixture with both whites and negroes, along with the consequent loss of ethnological characteristics, and the rude virtues which they might, as savages, have possessed. It is these Moskito Indians who occupy the country about Greytown and Bluefields, between the Republics of Nicaragua and Honduras; who have their chief settlement near Cape Gracias à Dios, and who claim the mouth of the river San Juan. It is the Moskitos, who consider themselves to be wholly independent of the Spaniards, but protected by the British, to whom their king has assigned such territorial grants as we now hold on their coast. They have been the cause of political complications between ourselves and the United States more than once, and are likely to be so again. They, and the tract they occupy, their political rights and their political pretensions, all want more notice on the part of the English public than they have met with. They are clearly and definitely separated from the tribes around by their language. This requires an interpreter to make it intelligible to their next neighbours. It is eminently smooth and harmonious; rarely tolerates two consecutive consonants in the same syllables, and wants the sounds of *f* and *v*. It has taken but few words from the Spanish, though several from the English, *e. g.*:—

Ox, bip (beef).
horse, haras.
cat, pus (puss).
goat, gut.
ass, berico.
mule, miul.
domestic hog, kuerko (puerco, S.)
coffee, kapi.
tobacco, twaka.
sugar-cane, kenio (cana, S.)
salt, sal.
axe, hasa (hacha, S.)

price, prais.
must, mus.
God, God.
Devil, Debil.
heaven, heben.
mercy, mersi.
bless, bles.
thanks, tant.
thousand, tausan.
lend, lend.
hair, hire.
work, wurk.*

Wulasha is the name of the evil-spirit, *Liwaia* of the water-spirit.

At the back of these, and southwards, lie the mountain-tribes of Nicaragua, well described by Mr. Squier; and on the Lake of Nicaragua, according to the statements of many an earlier author, now verified by the writer last mentioned, the remains of a Mexican colony, characterized, even at the present moment, by the use of the Mexican language.

In Costarica and Veragua we have the Indians of the Isthmus—Western Veragua being the country of the ancient Dorachos, and the country of the ancient Dorachos being rich in archæological remains. The tombs are of two kinds. One consists of flat stones, put together after the fashion of coffins, and covered with soil—the contents being earthen vases, rounded agates, and small images of birds in stone—eagles most probably—such as are found in Mexico, and on the Moskito shore. It seems to have been the custom to wear them round the neck as ornaments. The more frequent form, however, of tomb is the cairn, a rude heap of pebbles, in which we find no eagles, no ornaments, but only one or more stones used for grinding corn. At Caldera is to be found a rock covered with figures. One† "represents a radiant sun: it is followed by a series of heads, all with some variation, scorpions, and fantastic figures. The top and other sides have signs of a circular and oval form, crossed by lines." Height, fifteen feet. Characters, an inch deep.

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* Transactions of the American Ethnological Society, vol. ii. p. 237.

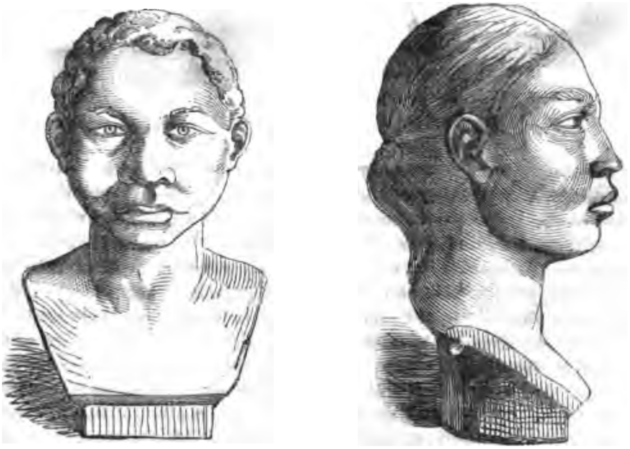
† Seeman's Voyage of the "Herald," vol. i. p. 313.

But the Dorachos are extinct; so that it is only in *northern* Veragua that Indian tribes still exist. These are the Savanerics, who are most numerous near the village of Las Palmas. One of their chiefs considers himself to be the descendant of Montezuma, and to a certain extent his successor and representative; since he sends every year a legate to Santiago to protest against the occupancy of the Spaniards, and to assert his own territorial right. They hunt, and fish—at least they poison the water with the pounded leaves of the barbasco. When a dead body is to be disposed of, it is wrapped in bandages, dried over a fire, laid on a scaffold, with meat and drink beside it; and when dry, interred. West of the Savanarics, and in Panama, come the Manzanillo, or San Blas Indians; and beyond these, on the River Chepo, the Bayanos—warlike, and independent. Then the Cholo tribes from the Gulph of San Miguel, on the south of the Isthmus, to the northern frontier of Ecuador. They may be traced along the coast "by their peculiar mode of raising their habitations upon poles six or eight feet above the ground." This form of architecture will appear again, *i. e.* when we come to the *Waraws.*

The contrast between large and small areas, which we have already seen in Asia and *North* America, repeats itself in *South* America, where the analogues of the Athabaskans, Algonkins, &c., are as follow:—

The Quichua stock follows the line of the Andes from the equator to 28° S. Lat.—spreading, in one point, as far eastwards as Tucuman. Like the Algonkins, the Quichuas have encroached and conquered; and just as the Iroquois area is surrounded by Algonkin occupancies, the Aymaras (between 15° and 20° S. Lat.), are surrounded, or nearly surrounded, by Quichuas. The Quichua is the name of the language of Peru, the ancient civilization of the Quichuas and Aymaras being that of the Mexicans and the Yucatecos (or people of Yucatan).

The Caribs.—The Caribs take the same prominence in Venezula that the Quichuas do in Peru, extending from the frontier of New Grenada to French Guiana. *There*, as well as in English, Dutch, Spanish, and Brazilian Guiana, the numerous

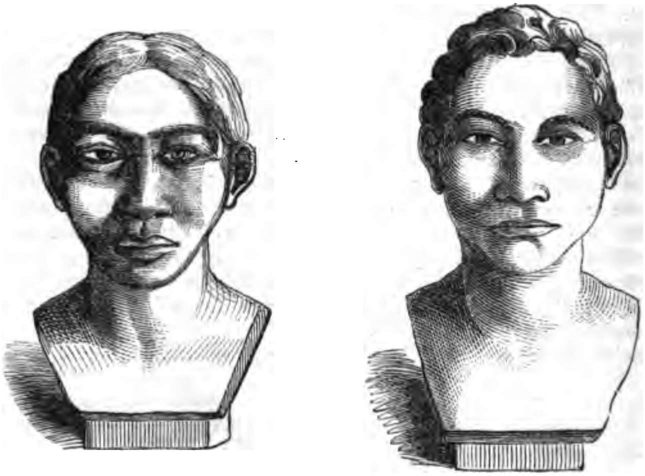


CARIBS.

1.—*Macusi.* 2.—*Macusi.*

divisions and subdivisions of the Carib groups, constitute the bulk of the Indian population. In Trinidad, too, part, at least, of the early population was Carib, as it also was in the Antilles. Cannibalism, and the habit of flattening the head, are Carib customs.

The distribution of the Quichuas is unique. Their area is large, and, at the same time, mountainous. Nowhere else does this conjuction occur. As a general rule, mountains isolate; levels connect. But the South American areas are remarkable for another peculiarity. They are greatly determined by the courses of *rivers;* being *fluviatile*, so to say. Now the Orinoco, and the Rio Negro, are the Carib water-courses.



CARIBS.

3.—*Macusi.* *Arecuna.*

But far more remarkable than any of the Carib phenomena is the distribution of

The Guarani.—It matters little from what point we begin to consider it. Perhaps the mouth of the Amazons is as convenient as any. If this be our starting point, we may follow the coast southwards, and in the direction of the River Platte. In nine cases out of ten, as often as the earlier Portuguese adventurers came upon an Indian population occupying the sea-shore, that population spoke a language which they called *Tupi*, *Tupi*naki, *Tupi*nambis, or something similar in the way of a compound of the root *tup*, and which they found to be mutually intelligible with the forms of speech spoken in several distant districts elsewhere. If they landed on the parts about Bahia, the language was akin to what they had previously heard at Olinda, and what they would afterwards hear at Rio Janeiro: and so on along the whole sea-board. Hence they were Tupi forms of speech as far north as the Island of Marajo, Tupi forms of speech as far south as Monte Video, and Tupi forms of speech in all (or nearly all) the intervening points of the coast. The fishermen of the Laguna de los Patos spoke Tupi. The Cahetes of Bahia did the same. So did the Tamoyos of the Bay of Rio Janeiro; and so the Tupinaki, Tupinambi, and Tupinacs—the Tupi Proper. This made the

Tupi pass for the leading language of Brazil; so long, at least, as Brazil was known imperfectly, or along the sea-coast only.

It was soon, however, noticed that, as a general rule, the Tupi of Brazil was spoken to only an inconsiderable distance inland, *i. e.*, until one got to the province of San Paolo, going southwards. In Goyaz, in the hill-ranges of Pernambuco, Bahia, Porto Seguro, &c., came forms of speech which those who spoke the Tupi separated from their own,—forms of speech of the barbarians (so to say) of the interior, as opposed to the more civilized mariners of the coast. The Botocudo, the Canarin, the Coroado, the Coropo, the Machacari, the Camacan, the Penhami, the Kiriri, the Sabuja, the Gran, the Timbyra, and a vast list of other Brazilian Indians besides, were different from and other than the Tupi. But this distinction between the coastmen and the inlanders ceases as we go southwards.

In Entre Rios, Corrientes, and Paraguay, the Tupi tongue was spoken inland; but not under the name of *Tupi*. In Entre Rios, Paraguay, &c., the designation was Guarani. This gave us a *Tupi-Guarani* class of languages, in which it was not very incorrect to say that the Tupi were the Guarani of Brazil, and the Guarani the Tupi of Paraguay. The *chief* difference was a verbal and nominal one.

But this was not all. On the watershed between the rivers La Plata and Amazons, on the frontier of the Aymara country, and in the Peruvian province of Santa Cruz de la Sierra, three other tribes spoke a language more or less Guarani, viz., the Chiriguanos, the Sirionos, and the Guarayos.

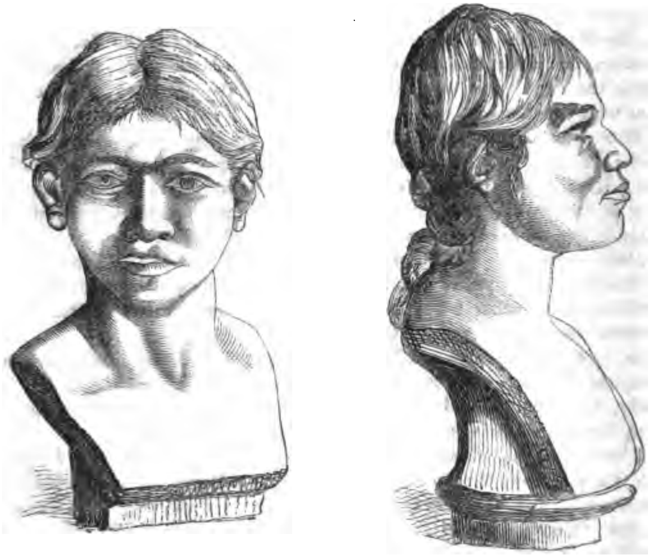
Again, on the rivers Napo and Putumayo, and other feeders of the *upper* Amazons, the Omaguas, Cocamas, and Cocamillas were Guarani. And—

Lastly, all along the main stream of the Amazons we find populations akin to the Tupi, Guarani, or Omagua, whichever name we chose to apply.

Now this Omagua, Guarani, Tupi, or Tupi-Guarani distribution is eminently *fluviatile*, *i. e.* it follows the lines of the great rivers. Hence the best provisional view that we can take, as to the diffusion of so important a stock, may be to consider the Siriono and Guarayo districts as the original localities. These are common to two river-systems; so that, starting from these, the Omagua and Cocama branch may have reached the Amazons, whilst the Guarani reached the Parana and Uruguay rivers. Still the view is only provisional.

Next to the Peruvian Quichuas and Aymaras, the Guaranis give us some of the most civilized tribes of South America. On the other hand the *Mundrucu*, of the middle Amazons, can be shown by their language to be Guarani; the *Mundrucu* serving as the very type and standard of savage wildness. When a Mundrucu has slain an enemy, he cuts off his head, extracts the brain through the occipital *foramen*, washes the blood away, fills the skull with cotton, and then converts the whole into a kind of mummy, by drying it before the fire. The eyes he gouges out, and he fills up the orbits with colouring matter. Thus prepared, the head is placed outside his hut. On festive occasions it is placed at the top of a spear. Such is the history of the head of an enemy. Those, however, of friends and relations are preserved, and kept—though with certain differences of detail. Thus, on certain days dedicated to the obsequies and memory of the dead, the widow of the deceased takes his skull, seats herself before the cabin, and indulges either in melancholy lamentation, or in fierce encomium—the assembled friends meanwhile dancing round her.

The Chileno-Patagonians.—The name is more expressive than convenient. It indicates, however, by its very composition, the magnitude of the group to which it applies. When we get into Chili, we arrive beyond the limits of the Quichuas and Aymaras, and a new family makes its appearance, extending over Chili, over the whole of the country south of the River Platte, over the islands of the Chiloe Archipelago and Tierra del Fuego. Its divisions comprise (*a*) the Chileno (or Araucanian) Indians; (*b*) the Pampa Indians; (*c*) the Patagonians; (*d*) the Fuegians.



PAMPA GIRL.

The range of differences, in respect to physical form, is wide in this group; the range of differences, in respect to the geographical conditions under which they are found, being also wide; *e. g.*, there are the Andes of Chili, the level plains of the Pampas, and the insular character of the parts about Cape Horn; not to mention the fact of South America extending further in the direction of the Antarctic Circle than any other part of the world.

The minor divisions, the analogies of the Dioscurian and Oregon groups in Asia and North America, are numerous. Thus—

In contact with different parts of the great *Carib* area on the drainage of the Orinoco and Rio Negro, we have the Maypuri, the Saliva, the Achagua, the Taruma, the Ottomaca divisions—all falling into subdivisions. On the Uapes only, a feeder of the Rio Negro from the west, Mr. Wallace, the best guide in these parts, enumerates the following tribes:—Queianâs, Tarianas, Ananâs, Cobéu, Piraiurú, Pisá, Carapaná, Tapüra, Uaracú, Cohidias, Tucundéra, Jacami, Miriti, Omáuas.*

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* "Travels on the Amazon and Rio Negro," p. 481.

There is nothing here (it may be said) but names. Be it so. The number of them shows the extent to which the populations of South America are broken up into small sections. Multiply the above given list by the number of rivers in that continent, and, large as would be the result in the way of divisions and subdivisions, it would not be an incredible one.

The famous burial cavern of the Ataruipe, near the cataract of the Atures, on the Orinoco, belongs to a Saliva tribe, now extinct, or amalgamated with some other. It was visited, and has been described, by Humboldt. The cavern itself was natural. The number of prepared bodies amounted to nearly six hundred, well preserved, regularly arranged, each in a sort of basket, made of the petioles of the palm-tree, and called by the natives *mapires*, in form like bags, and of the size of the body they contained. Some were no more than ten inches, others as much as three feet, long; some held infants, some adults. The bodies, more or less bent, were so carefully placed inside them that no rib, none of the smaller bones, seemed wanting. The first step in the process of preparation was to scrape off the flesh from the bones with sharp stones; the second to prepare the bones themselves. There were three ways of doing this. One was simply to dry and whiten them by exposure to the sun and air; another was to stain them with annotto, or the *bixa orellana;* a third to varnish them with odoriferous resins. Besides these bags or baskets, earthen vases, half-baked, were found in the cavern, containing bones, greenish-gray in colour, oval in form, and as much as three feet in height and five in length. The handles were made in the shape of crocodiles or serpents, the edges bordered with meanders, labyrinths, and real *grecques*, in straight lines, variously combined.

On another frontier of the great Carib area, in British Guiana, we find, as tribes hitherto unplaced, the Wapisianas, the Tarumas, and the Waraw; the latter having always commanded the attention of ethnologists. His occupancy is the Delta of the Orinoco—a swamp; as is a considerable portion of the sea-coast to the south of it. If it were not for the straightness of his hair, the Waraw (writes Sir Robert Schomburgk) might be taken for a Negro. Doubtless he is dark-skinned; but I do not imagine that he has the Negro lip. His skin is dark, and dirt gives intensity to its natural darkness; for the Waraw is uncleanly even for an Indian. His language is certainly unintelligible to all his neighbours; neither has it been placed in the great Carib class, wide and capacious as that class is. Nevertheless it is far from being wholly isolate. It has miscellaneous affinities, and plenty of them. But the most notable characteristic of the Waraw is his industrial activity as a boat-builder. This furnishes nearly the whole of Demerara with canoes. They are made either of the *Cedrela odorata*, or of a tree called Bisi, and are sometimes fifty feet long and six feet broad.

When a suitable tree has been found, the Waraw builds a hut in its neighbourhood, which he occupies as long as the boat is being built. The floor of the hut must be some feet above the level of the ground; and this is effected by selecting a spot where the ita-palm grows in thick clusters. This is docked to the requisite height—the root and a part of the trunk being left standing. The trunk of the maneca-tree is then cut into planks, and made into a floor. Clay is laid on the floor, and a fire kept burning on the clay. The *Manicaria saccharifera* supplies the thatch. Meanwhile the boat-building goes on. By thus elevating the floor of his dwelling, the Waraw escapes the floods of the rainy season, which raise the water of the numerous mouths of the Orinoco several feet above their banks: Sir R. Schomburgk says three or four, others from twenty-five to thirty. It is different in different localities. Raleigh came in contact with the Waraws, whom he describes under the name of *Tivitivas*, adding that they fall into two divisions—the *Ciawani* and the *Araweete;* that "they are a goodly people, and very valiant;" that "in summer they have houses on the ground as in other places. In winter they dwell upon the trees, where they build very artificial towns and houses; for between May and September the river of Orinoco riseth thirty foot upright, and then these islands are overflowen twenty foot high above the level of the ground, saving some few raised grounds in the middle of them; and for this cause they are enforced to live in this manner."

The undoubted peculiarities of the Waraws have been exaggerated; and they have been described as men who *live in trees*—as *arboreal varieties* of the human species—even as *arboreal species* of the *genus homo.*

In contact with the *Guarani* come numerous tribes along the Amazons—numerous tribes between the Guarani and Carib frontiers—numerous tribes of the interior (*i. e.* the *non*-Guarani parts) of Brazil. Of the number of these, the following list gives a notion. It is one (and an imperfect one) of the *Brazilian* tribes which are *not* Guarani, Botocudos, Canarins, Goitacas, Machacari, Patachos, Camacans, Malalis, Cacriabas, Kiriris, Sabuyas, Cumanachos, Cachinesis, Araris, Chumetos, Pittas, Tactayas, Cames, Timbiras, Baccahirys, &c., &c. Most of these fall into divisions—many into divisions and sub-divisions.

Between the northern frontier of the Quichuas and the Isthmus of Darien come the tribes of New Grenada; little known, and, to a great degree, extinct. These, like those of Brazil, are counted by the dozen or the score.

Then there are the parts on the eastern, or Bolivian, side of the Andes.

To *Peru* belong—the Yuracares, the Mocetenes, the Tacanas, the Apolistas, the Maropas, with divisions and additions.

To *Bolivia* belong—

a. In the Mission of *Moxos*—the Muchojéonès, the Moxos, the Baurès, the Itonama, the Canichana, the Movima, the Cayuvava, the Itenes, the Pacaguara.

b. In the Mission of the *Chiquitos*—the Chiquitos, the Saraveca, the Otukès, the Covareca, the Curuminaca, the Curavè, the Tapii, the Curucaneca, the Corabeca, the Paioconeca.

In the district called *Chaco*, on the rivers Pilco-Mayo and Vermejo, feeders of the River Platte, we have the greatest amount of independent tribes, chiefly referable to a class called *Abiponian.* To this belong, with others, the Abiponians Proper, the Mbocobi and Toba, the Lenguas, the Payaguas, the Matagayos, the Guacurus, perhaps the Charruas, known, at present, only in fragments; whole sections of it being either extinct or incorporated. The original divisions, however, were as follow:—

1. The Charruas Proper; 2. the Chayos; 3. the Chanâs; 4. the Guenoas; 5. the Martedanes; 6. the Niboanes; 7. the Yaros; 8. the Minoanes; 9. the Caaiguas; 10. the Bagaez; 11. the Tapes. Of these the Chanâs and Niboanes inhabited, at the arrival of the Spaniards, the islands of the Uruguay, at the junction of the Rio Negro. The Guenoas and Martedanes connected themselves with the Portuguese of the Colonia del Sacramiento, and were at enmity with the Yaros and Minoanes. The Chayos are the first that disappear from history, probably from having become amalgamated with the Yaros.

The Charruas Proper, from the time of Solis to the year 1831, have lived the life of a nation of warriors, with their hand against every man, and every man's hand against them. Uninterrupted as was their hostility to the Spaniards, it was equally so against the other aborigines; so much so, that in no case do we find a common alliance against the common enemy to have existed;—on the contrary, the war against the Mamalucos, the Tupi, and the Arachanes, were wars of extermination. And so was the war against the Spaniards; except that the Spaniards were the exterminators. In 1831 the President of Uraguay, Rivera, destroyed the Charruas root and branch; so that at the present moment a few enslaved individuals are the only remains of that once terrible nation.

CHARRUA.

CHARRUA.

From eighty to one hundred families lived under the direction of a Tubicchó, or semi-hereditary chief, and when danger threatened the Tubicchós met and chose amongst themselves a leader. Whoever is chosen commands the obedience of the rest —the election is half council, half feast. Chicha is drunk; wounds are exhibited; exploits are recounted; the most worthy is selected from his peers. After this fires are lighted as beacons, and the warriors of tribes meet from all parts. When they can make the attack, they do it by night, and at the full moon.

I believe that this savage semi-heroic character of the Charruas is a fair sample of the wilder and more unsubdued Indians of Chili, Patagonia, and the Gran Chaco; also, that it is equally true of the Araucanians as described by Ercilla, and the Pampa Indians of Sir E. Head. And what is this but a repetition of the same features which we see in the corresponding parts of North America? Here, when we have got beyond the tropics, we find the Algonkin, Sioux, and Iroquois warriors, conterminous with, and (as the present writer believes) passing into the feebler Eskimo—these latter bearing the same relation to their southern neighbours as the Fuegians do to the northern ones.

Details could still be added; but the general distribution of the South American population over their large and small areas has, perhaps, been sufficiently attended to; since Africa, the south-western parts of Asia, and such parts of Europe as are not Turanian, still require notice.

Africa and the south-western parts of Asia will be taken first. The population hereof will all be thrown into one large class.

GROUP VIII.—THE AFRICAN STOCK.—*Organization:* Head rarely other than dolikhokephalic; hair rarely straight—always, with individuals resident on their native area, black; skin dark; in certain localities attaining the *maximum* amount of blackness. In such cases the hair is crisp, and the lips thick—*i. e.* the physiognomy is Negro.—*Languages:* Agglutinate.—*Area:* Africa, *minus* the Island of Madagascar (wholly, or in part), *plus* Arabia and parts of Persia and Syria.

The Aramæans, or populations speaking languages allied to the Arabic and the Hebrew, and called **Semitic.**—The Arabians, the Syrians, the Jews, and the Æthiopians of Abyssinia, constitute this class—a class pre-eminently characterized by its early civilization, and its monotheistic forms of belief. From the Jews, Judaism; and out of Judaism, Christianity; from the Arabs, Mahometanism has arisen: whilst the alphabet was either invented or promulgated by the Phenicians.

With the Jew the face is massive. With the Arab of Arabia, in his most (so-called) Caucasian form, the face is oval; forehead, vaulted; nose, straight or aquiline; lips, thin, even when thick not projecting; hair, wavy or curled; complexion, various shades of brown; limbs, spare. With the Arab of Africa the colour is sometimes nearly black, the frame more massive, and limbs more fleshy.

In Abyssinia, the country of the Æthiopian branch, the transition to the true African of Africa is the clearest; the Amharic and Gafat tribes graduating into the Agow, Kaffa, Woratta, and Yangaro divisions (based on the affinities of language) of the Gonga division. There are also other points of contact, *e. g.* with the Danakil and Galla tribes.

The Ægyptians.—The early civilization of the valley of the Nile was the civilization of the ancestors of the present Copts, who are still to be distinguished from the dominant population of Ægypt, which is Arab. They are Christians rather than Mahometans, and, although their tongue no longer exists as a spoken language, there is the Coptic literature of the Coptic, or Ægyptian, Church. This gives us in an alphabet derived from the Greek, the Ægyptian of the Hieroglyphics in a form—modern as compared to them, though ancient as compared to the languages of the nineteenth century.

The following is the physiognomy of the modern Copt—*i. e.* of the modern representative of the Ægyptian of the Pharaonic epoch as opposed to the Arab. The hair is black and crisp, or curled; cheek-bones, projecting; lips, thick; nose, somewhat depressed; nostrils, wide; complexion varied, from a yellowish to a dark brown; eyes, oblique; frame, tall and fleshy; physiognomy, heavy and inexpressive.

The Amazirg.—The Amazirg group contains the *native* populations of the desert of the Sahara, of the greater part of the country to the north thereof, and of the Canary Islands. Hence it occurs in the oasis of Siwah near the Ægyptian frontier, in Fezzan, Tunis, Algeria, and Morocco. The descent of the Amazirg is from the ancient Gætulians, Numidians, and Mauritanians; their chief divisions, the Ammonians (Siwah being the ancient Ammonium), the Kabails of the range of Mount Atlas, the Tuariks (of the Sahara), and the Guanches. This last was the name of the aborigines of the Canary Isles, now extinct.

The Amazirg populations have always receded before populations more encroaching than themselves—at least on their northern frontier; *e. g.* before the Phenicians, Greeks, and Mahometan Arabs.

The mountaineer tribes of the Amazirg are the Kabails; the desert tribes the Tuarik. Of these, the social organization is such as we usually find in similar localities. It is that of the Arab, the Turk, and the Affghan; where the spirit of pedigree and the pride of blood operate upon the framework of the society, instead of the possession of land or civic rights. Less like an ocean of arid and inhospitable sand than a rocky wilderness, sometimes stretching into vast flats, sometimes rolling out in undulations the Western Sahara, though scantily supplied with vegetation in its less favoured parts, has its oases, where there are springs of water, date-trees, corn and vegetables, and shade. These are the occupancies of the more settled tribes, the *Kel-ouees*, who live in villages. To these the *Tuarik el badîa* stand in opposition; for Tuarik el badîa is the Arabic name of the migratory tribes of the Sahara. The dark complexion of more than one of the Tuarik tribes has been noticed, *e. g.* those of the Wadreag are stated, by Mr. Hodgson, to look like Negroes—so black is their skin, and so crisp their hair. Yet he suspects no Negro intermixture.

The Amazirg tongues are often called *Berber*. From the extent to which they are allied to the Hebrew and Arabic, they have also been called *sub*-semitic.

The Nilotic Class.—This is provisional, and, more or less, artificial. It is important, however, because it is the one by which the so-called *semitic* and *sub*-semitic classes are connected with the true African. That *all* the populations of the Nile do not come under this denomination has been seen—the Ægyptians forming a separate group, the Æthiopian branch of the Aramæans doing the same. So that the group is provisional, and the name other than unexceptionable.

The divisions of this Nilotic class are—

a. The Ilmorma (Galla), Somauli, and Afer (Danakil), pastoral tribes to the south, east, and west of Abyssinia. Colour varying from a deep black to a brownish-yellow. Stature, tall; bodies, spare, wiry, and muscular; frontal profile, vaulted; nose, often straight, or even arched; lips, moderate; hair, often hanging over the neck in long twisted plaits.

b. The Agows; probably the aborigines of western Abyssinia, encroached upon by the Ethiopians, occupants of the provinces of Damot, Lasta, and the parts about the Lake Dembea.

c. The Nubians, of Nubia and Dongola, *i. e.* of the valley of the Nile, between Egypt and Abyssinia. "A long oval countenance," writes Rüppell, "beautifully-curved nose, somewhat rounded towards the top, proportionately thick lips, but not protruding excessively; a retreating chin, scanty beard, lively eyes, strongly frizzled (but never woolly) hair, remarkably beautiful figures, generally of middle size, and a bronze colour, are the characteristics of the genuine Dongolawi."

To this division the evidence of language attaches the unequivocally Negro tribes of Kordofan and Darfur, and, more or less, of Sennaar.

d. The Bishari of the desert and mountains between the Nile and Red Sea. These are, probably, either Egyptian or Nubian—so that the class is provisional.

The Galla and Somauli of the parts south of Abyssinia lead us to the great

Kaffre Family.—Like the Amazirgs, the Kaffres (in the wide and generic sense of the word) extend over a vast space, from east to west. Indeed, they stretch all across the continent. The coast of Zanzibar is Kaffre; the valley of the Gaboon River, and the parts north of Angola and Loango, are Kaffre. *Southwards*, the frontier of the Cape Colony is Kaffre. Hence the Kaffre area extends from the Cape to the Equator; even beyond the Equator—and that on both sides of Africa.

From this, however, must be substracted the area of

The Hottentot Family.—This means a large district on the western coast, south of Benguela, but of undetermined magnitude. How far it extends into the interior is uncertain. Its southern limit, however, is the cape Agulhas, *i.e.* the southernmost promontory of Africa. The parts east of Walvisch Bay, the parts east of Angra Peguena, the drainage of the Orange River, are all Hottentot. Much of the great Kalahari Desert is Hottentot.

The Hottentot stock has a better claim to be considered as forming a second species of the *genus homo* than any other section of mankind. It can be shown, however, that the language is no more different from those of the world in general than they are from each other. It has special affinities with the languages north of the Equator, *i.e.* beyond the Kaffre area.

The Hottentot is in stature low, with slight limbs; colour, more brown or yellow than black (that of new-born children said to be nearly white); cheek-bones, prominent; nasal profile, depressed; hair, in tufts rather than equally distributed over the head. It is thus described by Barrow: "It does not cover the whole surface of the scalp, but grows in small tufts, at certain distances from each other, and, when clipped short, has the appearance and feel of a hard shoe-brush, except that it is curled and twisted into small round lumps, about the size of a marrow-fat pea. When suffered to grow, it hangs on the neck in hard twisted tassels, like a fringe."

Other peculiarities of organization could be added. It is sufficient, however, to repeat the statement previously made, viz., that the differences of speech by no means coincide with the differences of form.

Some fifteen divisions or sub-divisions of the Hottentot family are extinct. There are extant, however—*a*, the Gonaqua; *b*, the Koraqua; *c*, the Namaqua; *d*, certain populations of the Dammara country; *e*, the Saabs (or Bushmen).

There now stands the area which is bounded by the southern frontier of the Sahara on the north, by the equator (there or thereabouts) on the south, by the Atlantic on the west, and by the water-system of the Nile (there or thereabouts), on the east.

This is the part where the most *Negroes* are to be found—*Negro* meaning not merely those Africans whose skin is black rather than brown, but also those who, along with this blacker hue, present the further characteristics of woolly or cottony hair, thick lips, and a yellowish sclerotica, with other differences of greater or less, real or supposed, importance. The extent to which the physiognomy of a given African may be *Negro* is a mere matter of degree, a simple question of *more or less*. At least such is the evidence of language, and such the inference to be drawn from the study of the physical conditions of soil and climate under which the more extreme Negro forms are found. Every division, founded on the affinities of language between the two tropics, has either a Negro section or a section approaching the Negro—no matter how much its other members may be other than Negro. On the other hand, the most Negro divisions of the whole continent present instances of lighter-coloured varieties; varieties lighter in colour, and in other respects departing, more or less, from the Negro type.

Thus, the Amazirg class gives us certain darker varieties, *e. g.* the Wadreag already noticed.

The Kaffre does the same. On the western coast the change from Negro to Non-negro—from black to brown—sets in between Benguela and the Damara country, to the back of Walvisch Bay. On the east it extends further south still—to Inhambane, or even below Inhambane.

The Nilotic group gives us Negroes; *i. e.* in Sennaar and on the eastern feeders of Lake Tshad.

Abyssinia has its *Shankali* districts, the Abyssinian name for *Black*. In fact, if we take the whole continent of Africa, we may go so far as to say that the Negro physiognomy is the exception rather than the rule. To verify this, we may ask, What are the true Negro districts of Africa? What those other than Negro? To the former belong the valleys of the Senegal, the Gambia, the Niger, and the intermediate rivers of the coast, parts of Sudania, and parts about Sennaar, Kordofan, and Darfûr; to the latter the whole coast of the Mediterranean, the Desert, the whole of the Kaffre and Hottentot areas south of the line, Abyssinia, the Middle and Lower Nile. Truly this leaves but little room for the typical Negro.

All the intertropic groups of Africa give us Negroes, and every Negro group gives us some brown, rather than black, divisions. Thus: There is the great division of the Fulahs. All its members are more brown than black. *Some* have been designated by the epithet *red*.

There are the Nufi of the old red-sandstone tracts to the back of the delta of the Niger. These, also, are brown rather than black.

There are the Ediya of Fernando Po, which, being one of the few African Isles of any size, will be noticed somewhat more in detail.

Within four degrees of the equator, and not more than twenty miles from the parts about the Cameroons River on the mainland, the island of Fernando Po rises boldly and abruptly from the sea, primitive and volcanic in respect to its geological structure, and with one portion of it which rises to the height of 11,000 feet. This is Clarence Peak, the highest part of its chief mountain-range. Of these ranges there are two, and they run in a north-easterly direction, breaking the island up into precipices and ravines. From these there is a good supply of fresh water; but in *no part of the island* (and this is the express statement of Mr. Thompson) *has there been discovered any alluvial deposits.* Fog and forest equally contribute to give it a truly insular climate. The hills are thickly wooded, even to the higher ranges; whilst the rainy season lasts from May to December. Then comes what is called the "smokes"—a thick fog enveloping the island and covering a portion of the sea around it.

The flora of Fernando Po exhibits several marked *differentiæ* to that of the mainland. The fauna does so still more. The human occupants, though referable from the evidence of their language to a continental origin, are, nevertheless, members of a separate division of the family to which they belong. Divided into about fifteen different villages, and amounting to, perhaps, as high a number as 15,000 for the whole island, the mutually unintelligible languages are, at least, two. One of these is the Ediya, of which we have a sufficient vocabulary. The other is wholly unrepresented. We are informed, however, that when the people from Clarence Cove visit one of the villages on the south-east, for the sake of purchasing pottery, the trade is carried on by signs.

Again, in certain villages about West Bay the language is also unintelligible to an Ediya; though, whether it be so because it is identical with the form of speech just noticed, or because it constitutes by itself a third variety, is uncertain.

On the other hand, the physical appearance of the natives is the same throughout the island. The face is rounder, the nose less expanded, the cheek-bones less high, and the lips thinner than in the typical Negro. The skin, too, is *lighter*, *and the hair longer and softer*. Still, the general physiognomy is African. The lower extremities are disproportionately stout; and this makes them appear shorter than they really are. Exercise on foot, and the habit of sitting with the legs doubled up to the chin, are the accredited causes of this. The hands and feet are small. *Copper* and *olive* are the terms which have been used to denote the colour of the Ediya; and, as a proof that they have not been applied over-hastily, Captain Botelar checks himself from assuming an intermixture of white blood to account for it, inasmuch as "the features were all of the same cast." Without insisting upon the degree of these olive or copper tints, as opposed to black, I draw attention to the fact of their occurrence in what we call a *high* island of Equatorial Africa.

Does this suggest the rule for the distribution of the Negro populations of Africa? If not, let the reader remember Captain Beechy's observation respecting the darker and lighter Polynesians. The latter occur on the *high*, the former on the *low* islands.

A Negro is an intertropical African in a humid alluvial locality. Hence no class-named *Negro* can be strictly ethnological, since the term denotes elements other than those of affiliation and descent. Thus in respect to descent, the Negro of Sennaar has his closest relations in the way of language, manners, and blood with the Africans of Nubia, Abyssinia, and the parts about his own country. Not so, however, his physical conformation. These are with the Africans of Senegambia and Guinea,—a fact brought about by the common conditions of heat, moisture, and a low sea-level.

Hence, too, the group for the remaining populations of Africa will have no special name, but simply be said to contain—

The Africans of the Northern Tropic.—Here, if we begin on the west coast, and at the south-western extremity of the Sahara, we have, more or less provisionally arranged—

1. The Wolofs, on the *Lower* Senegal (*Negroes*). Allied to these, but with other miscellaneous affinities as well, the Sereres, the Serawolli, &c.

2. The Mandingos (*Negroes*), with the allied Bambarrans, Jallonkans, Susu, Vei, Mendi, Kuranko, &c. This large class graduates into one containing the populations, speaking languages akin to

3. The Grebo of the Krumen (*Negroes*). Not very remote from the Grebo class come the tribes akin to

4. The Fanti and Ashanti (*Negroes*) of the Gold Coast. Then—

Intermediate, transitional, and with miscellaneous affinities, come—

a. Between the Gambia and 10° N. Lat., the Felups, the Papels, the Bissago Islanders, the Bagnon, the Naloo, the Sapi, &c., Islanders, or occupants of *alluvia* at the mouths of rivers—*Negroes*.

b. Between Cape Palmas and the Gold Coast, the Avekvom—*Negroes*.

c. In Dahomey, the Delta of the Niger and the country to the interior, are the Whidah, the Ibo, &c., &c.—*Negroes*.

But the Nufi of the higher country are lighter-coloured, as are the Fulas of the watershed between the Senegal and Gambia, and the Ediya of Fernando Po, as has been already stated.

In the direction of Lake Tshad, from west to east, we have the Yebu, the Sungai, the Haussa, and Bornui languages, all spoken by Negroes, or approaches to the Negro; and, on the island of Lake Tshad, the Biddumas. South of it, the Begharmi; and south of the Begharmi, the Mandara. To the north of Bornu lie the Tibbus of the Desert; to the south of the Mandara, the Kerdi, with which our notices in this direction end. The Kerdi belong to a wilder and more mountaineer population than any hitherto enumerated. "On penetrating," writes Denham, "a short distance in this direction, with some people from Mandara, we saw the inhabitants run up the mountains quite naked, with ape-like agility. On another occasion, a company of savages were sent from a Kerdy, or Pagan village, termed Musgow, as a peace-offering, to deprecate the Sultan, who was on the eve of making a kidnapping expedition into their country. On entering his palace they threw themselves upon the ground, pouring sand upon their heads, and uttering the most piteous cries. On their heads, which were covered with long, woolly, or rather bristly hair, coming quite over their eyes, they wore a cap of the skin of a goat or some animal like a fox; round their arms and in their ears were rings of what appeared to be bone, and around the necks of each were from one to six strings of the teeth of the enemies they had slain in battle; teeth and pieces of bone were also pendent from the clotted locks of their hair; their bodies were marked in different places with red patches, and their teeth were stained of the same colour. Their whole appearance is said to have been strikingly wild and truly savage. Endeavours to set on foot intercourse with them were in vain. They would hold no communication; but having obtained leave, they carried off the carcass of a horse to the mountains, where the fires that blazed during the night, and the savage yells which reached the valley, proved that they were celebrating their brutal feast."

East of Lake Tshad the Negro tribes belong, according to the evidence of language, to the Nilotic division.

The Gonga class belonging to Enarea; and a large tract south of Abyssinia is, probably, on the northern frontier of the Kaffre area. With the Kerdi and Gonga districts the *terra incognita* begins.

GROUP IX.—THE EUROPEAN GROUP.—*Physiognomy:* Caucasian in the wider and more inconvenient sense of the term.—*Languages:* Either unplaced, or Indo-European (so-called).—*Area:* Western, Central, and Southern Europe.—*Divisions:* A 1. The Basks; B 2. The Skipitar; C 3. The Kelts; D 4. The Greeks and Latins; 5. The Sarmatians; 6. The Germans.

The three divisions marked D are easily, conveniently, and accurately looked on as sections of some higher denomination—species (so to say) of a genus. To this, most writers add the Kelts; some the Albanians. All exclude the Basks. The name of this higher class, when it is limited to the divisions under D, is Indo-*Germanic;* when extended to D and C as well, Indo-*European*. The present writer objects to it in either form; holding it to be a word as erroneous and inconvenient as *Caucasian in the wide sense of the term*. Each, however, keeps its place, and each must be used, however unfit for use.

European ethnology bears much the same relation to the ethnology of the other parts of the world that microscopic anatomy does to descriptive. The main facts, respecting the physical and mental character of such populations as the Greek, Latin, German, &c., are known to us from *history*. Hence the more minute questions of intermixture, civilizational influences, shades of national character, and the like, constitute the department of the European investigator. This will make the notices of the European classes brief; their civil history being supposed to supply their characteristics, and that history (in its generalities, at least) being supposed to be known.

The most unfixed of the European divisions, though probably not very far removed from the Kelts, are

The Basks.—In the Spanish province of Biscay, and in the more mountainous parts of Navarre and Gascony, we find the Basks, a population whose language has the same relation to the Spanish and Portuguese as the Welsh has to the English. It is the remains of the ancient language of the whole country.

Considering its mountain locality, and its position at the north-western extremity of the country, on the one hand, and the undeniably recent origin of the present Spanish and Portuguese, on the other, this is no more than is expected *à priori*.

Further proof, however, has been supplied by the researches of ethnographical philologists, most especially by those of W. von Humboldt. In an elaborate essay, first published in Vater's Appendix to the *Mithridates*, that writer analyzes the names of the ancient Spanish rivers, mountains, and tribes, and shows that, whenever they have a meaning at all, that meaning is to be found in the Bask.

He shows more, viz. that not only Spain and Portugal, but that the Aquitanian province of Southern Gaul was Bask as well; in other words, that the present language of Bilbao and Navarre was extended southwards, and that of Les Basses Pyrenees northwards.

Like the Skipitars, the Basks have yet to be definitely and satisfactorily placed. The *native* name is *Euscaldunac*. In speaking of the ancient tongue of the Spanish peninsula, it is convenient to call it *Iberic* or *Iberian*. In both Spain and Portugal the blood is more Bask than the speech; the affinities of the latter being with the Latin, the effect of the Roman invasion of *Hispania*.

Skipitars.—This is the native name of the populations of Albania; strongly contrasted in language, less so in physiognomy and habits, with the Greeks, Turks, and Slavonians around them. The Skipitars have yet to be definitely and satisfactorily placed.

Kelts.—In Ireland, in the Highlands of Scotland, and in the Isle of Man, we have Kelts of the *Gaelic*, in Wales and Brittany, Kelts of the British, branch. In Cornwall the ancient British language is extinct. In England the blood is more or less Keltic, with Anglo-Saxon modifications. In France it is Keltic with Roman. The language in the former case is German, in the latter Latin, as to its affinities. In both, however, the blood is, probably, more Keltic than the speech.

The Populations speaking the Greek and Latin Languages, and the Languages derived therefrom.—*Italian Branch.*—This contains the ancient Romans and the other populations of Central Italy. The conquests of Rome extended the language of this branch over Gaul, the Spanish peninsula, the Grisons, and the Danubian Principalities; in all of which countries the tongue is more Roman than the blood.

Hellenic Branch.—This contains the Greeks, ancient and modern; the latter with, an undoubtedly, the former with a probably, large amount of mixed blood: for the present writer derives even the ancient Greeks from Southern Italy, believing them to have been as little indigenous to the soil of Hellas as the Angles were to that of

England. On no other hypothesis can he reconcile the affinities between the Latin and Greek languages with the differences between the Greek and Skipitar, the Greek and Dalmatian, the Greek and all the forms of speech interjacent to the northern frontier of the Hellenic and Italian areas. If the chain of affinity extended across the districts to the north of the Adriatic, the languages for these parts should be either Greek or Latin, or else transitional to the two—which they are not.

Sarmatian.—This stock falls into two divisions, the Lithuanian and the Slavonic. The area of the former is Lithuania and Courland, with parts of Livonia and East Prussia; of the latter, Russia, Poland, Gallicia, part of Lusatia, Bohemia, Moravia, part of Hungary, Servia, and Illyria. In Poland and Bohemia the stock is, *perhaps*, the purest. In Russia there is much Ugrian; in Bulgaria, Turk; in Germany, German, intermixture.

Germans.—This means all the populations whose languages are akin to the German. In detail, it means the populations of Germany, Holland, England (and by extension the United States, Canada, Australia, &c.), Denmark, Norway, Sweden. the Feroe Isles, and Iceland.

The Dutch province of Friesland gives us the German stock in its greatest purity, *i. e.* freedom from foreign intermixture. Eastwards it becomes more or less Slavonic; westwards, more or less Keltic.

The element *Indo*, in the compound term *Indo*-European, must have suggested the question, What have the Greek, Latin, German, Slavonic, and Lithuanic languages to do with India? The answer to this is, that a language, in which the learning of ancient India is embodied, a language called the Sanskrit, is so like the tongues in question, especially the Lithuanic, as to come in the same class. No one doubts this. But how do we connect this Indian member with the European ones? By deducing the latter from Asia, or by deducing the former from Europe? So generally has the former of these alternatives been adopted, that the present writer knows no one except himself who is committed to the doctrine of the European origin of the Sanskrit. His reasons he has given elsewhere (*Taciti Germania*, with Ethnological Notes, and *Ethnology of Europe*). Hence in the map, illustrative of the present paper, no notice is taken of the supposed *Eastern origin* of the so-called Indo-Europeans; a conquest on the parts of certain Sarmatians of certain parts of Asia from Europe, being considered just as likely a fact as the undoubted conquest of European Hungary by certain Ugrians from Asia.

The doctrine that deduces the languages of Russia, Germany, Italy, Greece, &c., from India, deduces the present languages of India and Persia from the Sanskrit. In those, however, of the former country the grammatical structure is Tamulian; whereas in those of the latter there is next to no grammatical structure at all. Now, if the Sanskrit affiliation be true, this absence of inflections in the Persian is explained—the Sanskrit being highly inflectional. If the Sanskrit affiliation be true, the Persian dialects are uninflectional, because inflections once existent have been lost.

On the other hand the Dioscurian affinities lead to the notion that flexion in the Persian has yet to be developed. This the present writer believes to be the case. At the same time the question is full of complexities, and requires not only the present remarks, but those on the Persian and Dioscurian groups, to make even its general bearings intelligible.

With the group to which the Germans, the Sarmatians, the Greeks, and Latins belongs, ends the classification of the "Varieties of the Human Species," the main object of the science of *Ethnology*. It has already been stated that it is one of recent origin. As such, it has been in the hands of but few inquirers. Let us look at its origin and history. Its origin is, to a certain extent, two-fold. It began with the zoologists, and it also began with the investigators of language—each looking at it exclusively from his own point of view. Thus both the *System of Nature* of Linnæus, and the *Natural History* of Buffon, works of pure and special zoology, take cognizance of man —of *man as an animal*. And they take cognizance of him in two ways—first, in respect to his relation to the inferior animals; secondly, in respect to the different *varieties of the human species*. This distinction grows clearer as we proceed, and, by the time we approach the epoch of Blumenbach and Cuvier, the whole of the scientific nomenclature shows its reality and importance. Blumenbach, for instance, divides mankind into the Mongolian, the Caucasian, the American, the African, and Malay varieties; and these he considers in their relations to each other, without much troubling himself as to the characteristics by which they were, each and all, distinguished from the higher apes. Cuvier, on the other hand, after throwing the apes and monkeys into one order, Quadrumana (*four*-handed), falling into *genera* and *species*, makes Man the representative of another—Bimana (*two*-handed); of which there is but a single *species* of a single *genus*; though, upon this point, other naturalists have thought differently. Now the erect posture, the greater volume of the brain, the faculty of speech with its corresponding organization, the perfect mechanism of the hand, &c.—points that all the Bimana have in common with each other—are, at the same time, characteristics which distinguish them from the Quadrumana. And these are points, not of *Ethnology*, but of the closely allied science of *Athropology* (from the Greek word *Anthropos*=*man*).

Ethnology deals with the differences between the different *varieties of mankind; Anthropology*, with the difference between man and the lower animals. The extent to which a human being differs from the higher Quadrumana is a question of *Anthropology;* the extent to which a white man differs from a Negro, one of *Ethnology*. Such is the relation of Ethnology to *one* of its allied sciences—a relation that we best understand by taking a *naturalist's*, rather than a *historian's*, view of the subject.

But the naturalist's view is not sufficient of itself. The importance of such a study as Ethnology to the *civil* (as opposed to the *natural*) historian is transparently evident. On the other hand, a certain amount of historical knowledge is essential to Ethnology; as essential as a certain amount of *geographical*.

Geography is the basis of Ethnology, because it is the primary business of the ethnologist to compare *man with the earth he lives on*. He must do this, in order to see whether certain of the varieties of mankind may not agree with certain physical conditions of the surface of the terrestrial globe. He knows enough of our kind to know that the differences between the different divisions are very considerable; for, unless we know this, the distinction between a Negro and a white man, between a gipsy and native Englishman, have been lost upon him. And he also knows enough of the earth on which we dwell, to know that the differences of climate, sea-level, vegetable productions, and the phenomena of animal life, are, *at least*, as great as those between the most extreme varieties of our species. Unless he do this, he has read about rivers and mountains, islands and continents, deserts and forests, north-poles and south-poles, equators and circles, to no purpose. All this, however, is known—this, and more than this. Every one knows not only that there are such men and women as Negroes and Whites, and that there are such things as warm and cold climates, but also that, *as a general rule*, the Negro comes from a hot, the White from a temperate country.

To know this leads to the admission that certain physical differences, connected with the earth's surface, exercise a certain amount of influence upon the human organization; though whether it be great or whether it be small, whether it be sufficient or insufficient to account for all the varieties of our species, is another question. One thing alone is certain—viz., that there is *something* in soil, climate, and nutrition.

But *physical* influences are not enough. When Humboldt remarks that in savage nations there is but little difference between individual physiognomies, a series of *moral* agencies is suggested, and the extent to which civilization may modify form has to be considered. The conjoint study of these influences constitutes a branch of our science which may be called *Ethnological Dynamics*, or the doctrine of ethnological influences. The first volume of Prichard's great work is devoted to this. In the present sketch, the notice of the physical conditions under which a given population is found, is incorporated with the more properly descriptive part of the treatise. Still the division of our science thus designated should be borne in mind.

Let us now ask the meaning of a word, first suggested by Dr. Whewell in his *History of the Inductive Sciences*, and derived from the Greek words *palaios* (*= ancient*), and *ontologia* (*= the doctrine of existence*)—*palæontology*.

In certain judicial inquiries, writes Mr. Mill,* when we proceed upon circumstantial evidence, "we can conclude that a man was murdered, although it is not proved by the testimony of eye-witnesses that a man who had the intention of murdering him was present on the spot. It is enough if no other known cause could have generated the effects shown to have been produced." This is to infer the cause from the effect; or, to *to argue from effect to cause*—to *argue backwards*. In this way the geologist argues; in this way the archæologist argues; in this way the ethnologist argues; and, because the result of their arguments is the reconstruction of an earlier state of things out of a newer, their method is *palæontological*, and their several departments agree with each other in belonging to *palæontology*,—a long word but a convenient one, and one pretty generally adopted—by geologists at least. But this relation of ethnology to geology has already been noticed;† so that the way is now paved for the following concluding apophthegms, respecting the science before us, its relations, its method, and its object.

GENERAL APOPHTHEGMS.

I.—The natural history of man is chiefly divided between two subjects, anthropology and ethnology.

II.—Anthropology determines the relations of man to the other mammalia.

III.—Ethnology, the relations of the different varieties of mankind to each other.

IV.—Anthropology is more immediately connected with zoology; ethnology with history.

V.—Whilst history represents the actions of men as determined by *moral*, ethnology ascertains the effects of *physical* influences.

VI.—History collects its facts from testimony, and ethnology does the same; but ethnology deals with problems upon which history is silent, by arguing backwards, from effect to cause.

VII.—This throws the arena of the ethnologist into an earlier period of the world's history than that of the proper historian.

VIII.—It is the *method* of arguing from effect to cause which gives to ethnology its

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* "System of Logic," vol. ii. p. 27.

† See page 307.

scientific, in opposition to its *literary*, aspect; placing it, thereby, in the same category with geology, as a palæontological science. Hence it is the science of a method—a method by which inference does the work of testimony. Furthermore, ethnology is history in respect to its results; geology, in respect to its method. And in the same way that geology has its zoological, physiological, and such other aspects as constitute it a mixed science, ethnology has them also.

IX.—The chief ethnological problems are those connected with—1. the unity; 2. the geographical origin; 3. the antiquity; 4. the future destination upon earth of man.

X.—Ethnological facts are physical or moral—*physical*, as when we determine a class from the colour of the skin; *moral*, as when we determine one from the purity or impurity of the habits.

XI.—Moral characteristics are either philological (*i. e.* connected with the language), or non-philological (*i. e.* not so connected).

XII.—A *protoplast* is an organized individual, capable (either singly or as one of a pair) of propagating individuals; itself having been propagated by no such previous individual or pair.

XIII.—Hence—a *species* is a class of individuals, each of which is hypothetically considered to be the descendant of the same protoplast, or of the same pair of protoplasts.

XIV.—A *variety* is a class of individuals, each belonging to the same species, but each differing from other individuals of the species in points wherein they agree amongst each other.

XV.—A *race* is a class of individuals concerning which there are doubts as to whether they constitute a separate species, or a variety of a recognised one.

In the preceding pages no such word as *race* is used; this being the case because the writer believes that all the Varieties of Man are referable to a single species. Holding no doubts on this point, he makes no use of the term. Good writers, however, have occasionally defined *Ethnology* as the *Science of Races*: for this the present author would substitute *Science of Varieties*.

R. G LATHAM.

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ERRATA.

Owing to the compositor having inadvertently altered the paging of the Work, from pp. 352 to 376, after the first portion of this Index was in type, the references to the subjects therein occurring will be found (in the first four leaves of the Index) to be two pages backward. Thus the reference to "Abyssinia" should be 369 instead of 367; and so on.

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